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Parasitic Copepoda of Texas Coastal Fishes

By

DAVID CAUSEY

University of Arkansas, Fayetteville, Arkansas

This paper reports the parasitic Copepoda collected from fishes examined at Port Aransas. Texas, during June and July, 1952. I am indebted to Dr. Nell Bevel Causey for her unselfish aid in collecting copepods and for the identification of fish hosts, to Mr. and Mrs. Harold Doughty who kindly saved a number of specimens from the trash of their bait-shrimping activities, to Dr. Gordon Gunter for the use of facilities of the Institute of Marine Science and for many personal courtesies, and to Mr. K. J. Koratha of the Texas A. and M. College for several collections of copepods. To all these people I express my sincere thanks. Many unknown sportsmen, who fished along the pier and the jetty, gave me fishes and they also have my gratitude. I am again indebted to my dean, Dr. G. D. Nichols, for a grant from his travel fund.

Order Copepoda

Suborder Cyclopoida

Family Ergasilidae

Ergasilus lizae Krøyer, 1863

One collection from mullet gills, *Mugil cephalus* L. Mullet being bait instead of trash at Port Aransas, we examined only a few specimens.

Ergasilus mugilis Vogt, 1877

Four collections from the mullet, *M. cephalus* L., and one from the ten-pounder, *Elops saurus* L., the latter being an unusual host. In all cases the copepods were on the gills or the inside of the operculum.

Family Bomolochidae

Bomolochus attenuatus Wilson, 1913

Three collections from the striped sole, *Achirus achirus* L., the whiff, *Citharichthys spilopterus* Günther, and from an undetermined flounder, respectively.

Bomolochus exilipes Wilson, 1911

Two collections from the mullet, *Mugil cephalus* L. This is an unusual host for the species.

Bomolochus teres Wilson, 1911

One collection from the mullet, *Mugil cephalus* L.

Family Taeniacanthidae

Taeniacanthodes gunteri, n. sp.

Figures 1–7

This species is based upon a single mature female with egg strings attached. It was obtained from the under surface of the whiff, *Citharichthys spilopterus* Günther. The mounted specimen is deposited in the U. S. National Museum, with the catalog number 94094; the male unknown.

The cephalothorax is nearly circular, thus differing from that of the type species, *T. gracilis* Wilson, which is acorn-shaped. It accordingly lacks the knobs at the posterior lateral margins. The abdomen has two segments, but in this species the basal segment is much shorter than the terminal segment, while in *T. gracilis* the two segments are approximately the same length. The caudal rami are similar in the two species, but *T. gracilis* is shown with a short seta near the center of the outer margin, which I am unable to find in *T. gunteri.* The egg strings are generally similar, but in *T. gunteri* the two rows of flattened eggs overlap in such a way that the inner margins show a diamond-shaped beaded string instead of a zigzag line as in *T. gracilis.*

Wilson (1935) fails to state sizes for *T. gracilis,* and his plates 2 and 3 leave some uncertainty as to which scale, if either, applies to the figures of his species. Using both scales, *T. gracilis* would be, approximately, either 3.5 mm. or 6 mm. in total length. My single specimen of *T. gunteri* measures: total length, including caudal rami, 2.5 mm.; length of cephalothorax, 0.48 mm.; abdomen, exclusive of rami, 0.8 mm. in length.

Details of the structure of the appendages are difficult to determine in the whole mount of the single specimen available, and the figures of the second, third and fourth legs must be regarded as tentative until more material is available for dissection. There appears to be a general agreement of this species with *T. gracilis* in such details. *T. gunteri* appears to have four terminal setae on the first antennae, instead of the two shown for *T. gracilis.* No structural difference appears in the maxillipeds of the two species. The swimming legs are similar. *T. gunteri* shows two terminal setae on the fifth leg; Wilson shows three for *T. gracilis.* The fifth leg in *T. gunteri* appears to have two segments, a broad basal segment fringed with bristles along the posterior border, and a fused terminal portion very similar to what Wilson illustrates as the whole appendage.

In summary, *T. gunteri* differs from *T. gracilis* in being smaller, in the shape of the cephalothorax, in the relative lengths of the two segments of the abdomen, the appearance of the eggs in the strings, and in the structure of the fifth leg. It is named for Dr. Gordon Gunter of the Institute of Marine Science.

Suborder Caligoida

Family Caligidae

Caligus aliuncus Wilson, 1905

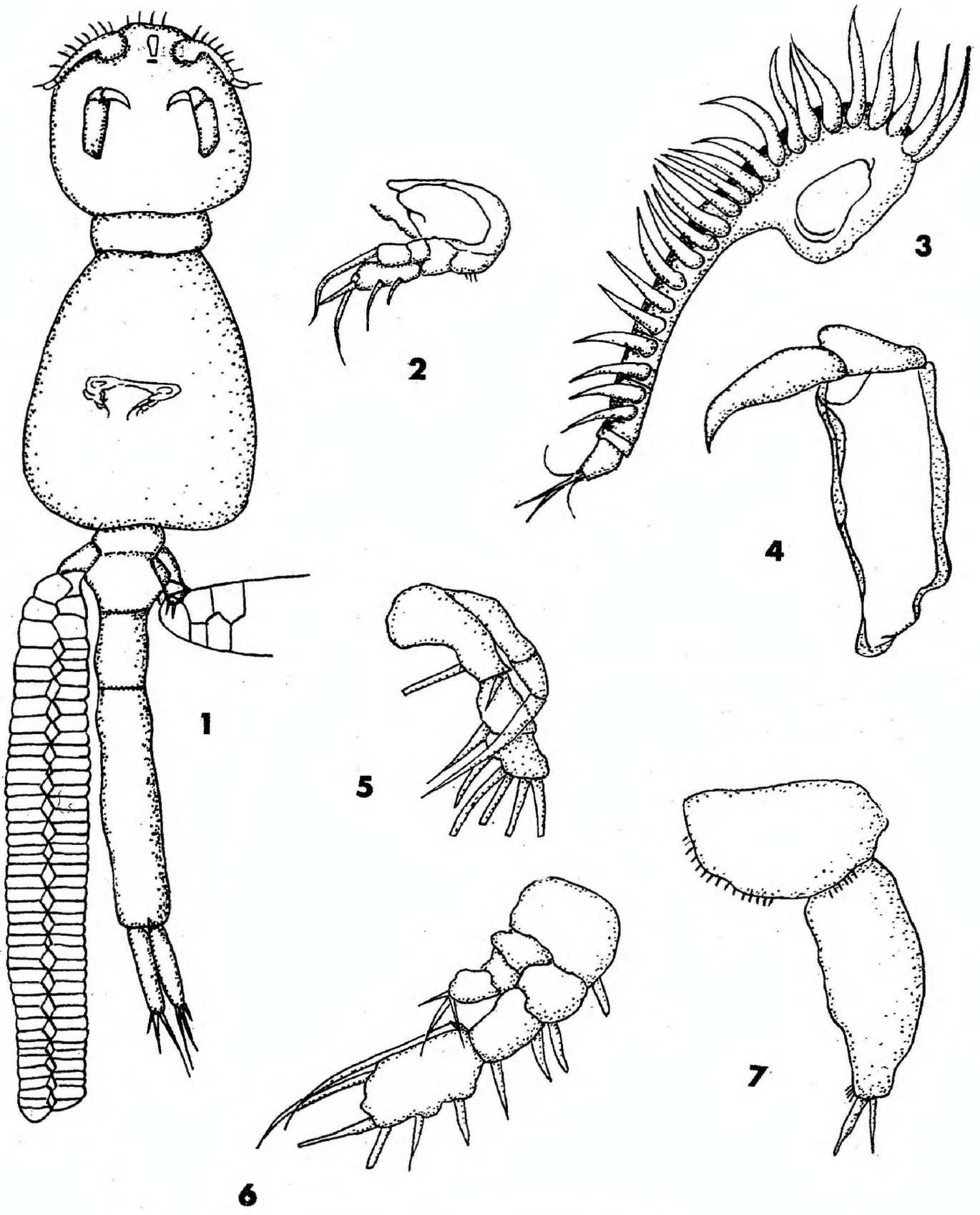
Two collections, one from the surface of *Rachycentron canadus* (L.), the cobia, and one from the gills of *Caranx hippos* (L.), the common jack. Both sexes of this relatively rare *Caligus* were present.

Caligus bonito Wilson, 1905

One collection from the surface of *Sarda sarda* (Bloch), the common bonito.

Caligus haemulonis Krøyer, 1863

Three collections from *Galeichthys felis* (L.), the sea catfish, on the surface, the gills, and in the mouth, and one collection from the mouth of *Sciaenops oscellata* (L.), the redfish.



FIGURES 1–7, *Taeniacanthodes gunteri*

Female:—1, ventral view; 2, fourth leg on genital segment; 3, antenna; 4, maxilliped; 5, third leg; 6, second leg; 7, fifth leg.

Caligus pelamydis Krøyer, 1863

Three collections from *Pogonias cromis* (L.), the black sea drum, three collections from *Scomberomorus cavalla* C & V, the king mackerel, and one from *Sarda sarda* (Bloch), the common bonito. They were variously distributed on the surface and gills of the hosts.

Caligus praetextus Bere, 1936

Two collections from *Galeichthys felis* (L.), the sea catfish, on the surface, one collection from the gills of *Lagodon rhomboides* (L.), the pinfish, and one from *Cynoscion nebulosus* (C & V), the spotted squeteague or speckled trout, on the gills. A single specimen was found on the one pinfish out of 33 examined.

Caligus productus Dana, 1854

One collection from *Scomberomorus maculatus* (Mitchill), the Spanish mackerel.

Caligus repax Milne Edwards, 1840

One collection from *Scomberomorus maculatus* (Mitchell), the Spanish mackerel, two from *S. cavalla* (C & V), the king mackerel, one from *Caranx hippos* (L.), the common jack, and one from *Prionotus sp.*, a sea robin. They occurred on the body surface, the gills, and in the mouth.

Caligus robustus Bassett-Smith, 1898

Two collections from *Caranx hippos* (L.), the common jack, and one collection from *Chloroscombrus chrysurus*, the bumper, all specimens occurring on the inside of the operculum.

Caligus tenax Wilson, 1913

One specimen from the gills of *Caranx hippos* (L.), the common jack.

Lepeophtheirus marginatus Bere, 1936

Ten collections from *Galeichthys felis* (L.), the sea catfish, and one from *Citharichthys spilopterus* Günther, the whiff. These are almost always on the surface of the host, but occasionally appear on the gills.

Lepeophtheirus monacanthus (Heller), 1865

Thirteen collections from *Galeichthys felis* (L.), the sea catfish, and two from *Bagre marina* (Mitchill), the gaff-topsail catfish. They are usually on the inside of the operculum, but are occasionally found on the surface or in the mouth. They often form patches on the inferior posterior angle of the operculum which may be from a half to three-quarters of an inch across. It is evident that this species prefers the conditions inside the operculum, whereas *L. marginatus* prefers the surface of the host.

Anuretes heckeli (Krøyer), 1863

Six collections from *Chaetodipterus faber* (Broussonet), the spadefish (locally the angelfish), and one collection from an undetermined filefish. All were found on

the gills and the inside of the operculum. Especial attention was given to this form in the effort to find more than one species of the genus, but all specimens were *A. heckeli.*

Echetus typicus Krøyer, 1863

Four collections from *Sciaenops ocellata* (L.), the redfish. They occur on the gills, where they cause noticeable damage to the tissue.

Tuxophorus caligoides Wilson, 1908

Three collections from *Rachycentron canadus* (L.), the ling or cobia. These occur on the surface of the fish.

Midias lobodes Wilson, 1911

A single collection from *Sphyraena barracuda* (Shaw), the great barracuda. The host had been caught some 18 miles out in the Gulf.

Family Euryphoridae

Euryphorus coryphaenae Krøyer, 1863

A single collection given to me, with the host indicated as *Rachycentron canadus* (L.), the cobia. This is usually found on *Coryphaena hippurus* (L.), the dolphin.

Elytrophora coryphaenae Pearse, 1952

A single collection from *Coryphaena hippurus* L., the dolphin. This is the second report of the species from the type locality. In the original description the figure was properly labeled, but in the heading the genus was inadvertently given as *Electrophora.*

Paralebion pearsei n. sp.

Figures 8–15

This species is based upon five collections from the tarpon, *Tarpon atlanticus,* where it occurs upon the fins and the body. The type and paratype of the female, catalog numbers 94091, 94093, and of the male, catalog number 94092, are deposited in the U. S. National Museum. It is named for Dr. A. S. Pearse of Duke University.

Female: In general appearance *Paralebion pearsei* lies between *P. elongatus* and *P. curticaudis.* The lobes at the "posterior corners" of the genital segment are shorter and more robust than those of *P. elongatus,* but longer than the lobes of *P. curticaudis.* The abdomen is relatively shorter than is the case in *P. elongatus,* and not as robust as in *P. curticaudis.* The abdomen does not appear to be divided into two segments, thereby agreeing with *P. curticaudis* and differing from *P. elongatus.* There is a marked difference in size between the species. *P. elongatus* has a total length of 10.8 mm., with the carapace 4.0 mm. long and 4.3 mm. wide (Wilson, 1935); and *P. curticaudis* has a total length of 6 mm., with the carapace being 2.65 mm. long and 3 mm. wide. *P. pearsei* is the smallest of the three, being 4.5 mm. in total length as measured from the anterior margin of the carapace to the tip of

the abdomen, or 5 mm. in length if measured from the anterior margin of the carapace to the posterior edge of the genital lobe, and the carapace is approximately 2 mm. in length and width. The egg cases are as long or slightly longer than the total length of the body, and friable, falling to pieces in the process of mounting.

The appendages are similar to those of the previously described species. The furca in *P. pearsei* is similar to that of *P. elongatus*, and hence differs considerably from Wilson's (1913) problematical figure for *P. curticaudis*. I am inclined to suspect that he had a fragment of the furca in the latter species rather than the whole. The maxilliped is relatively more robust than the corresponding appendage in the two other species. No unusual difference is apparent in the other appendages.

Male: Resembles that of *P. elongatus* (the male of *P. curticaudis* is not known), differing markedly in size. It has a total length of 3 mm., with the carapace 1.75 mm. in length and 1.5 mm. in width; while *P. elongatus* has a male 7.25 mm. in total length, with the carapace 3.54 mm. long and 3.87 mm. wide. The bristles of the caudal rami are noticeably longer in *P. pearsei* than are figured for *P. elongatus*.

This genus was established by Wilson (1911) upon specimens obtained from the mouth of an unidentified shark in Chesapeake Bay, the type species being *P. elongatus*. A second species, *P. curticaudis* (Wilson, 1913) was described from the gills of the red snapper, *Neomaenis aya*, from the West Indies. Wilson (1935) reported *P. elongatus* from the gills of the short-nosed shark, *Hypoprion brevirostris*, in the Dry Tortugas, and Bere (1936) reported it from the mouth of the bay, dusky, and spot-tip ground sharks in Florida, Finally, Pearse (1948) reports *P. elongatus* from the sharp-nosed shark, *Scoliodon terrae-novae*, taken at Beaufort, N. C. The present species may have been overlooked because of its small size but more likely because of the phenomena associated with a tarpon catch. The landing of the tarpon with a gaff, dragging it the length of the pier to be measured and weighed, and then to be photographed, first with its captor and then any number of piscatorial prevaricators, means that by the time the collector may approach, any copepods not rubbed off by the handling will probably have dropped off or have dried up.

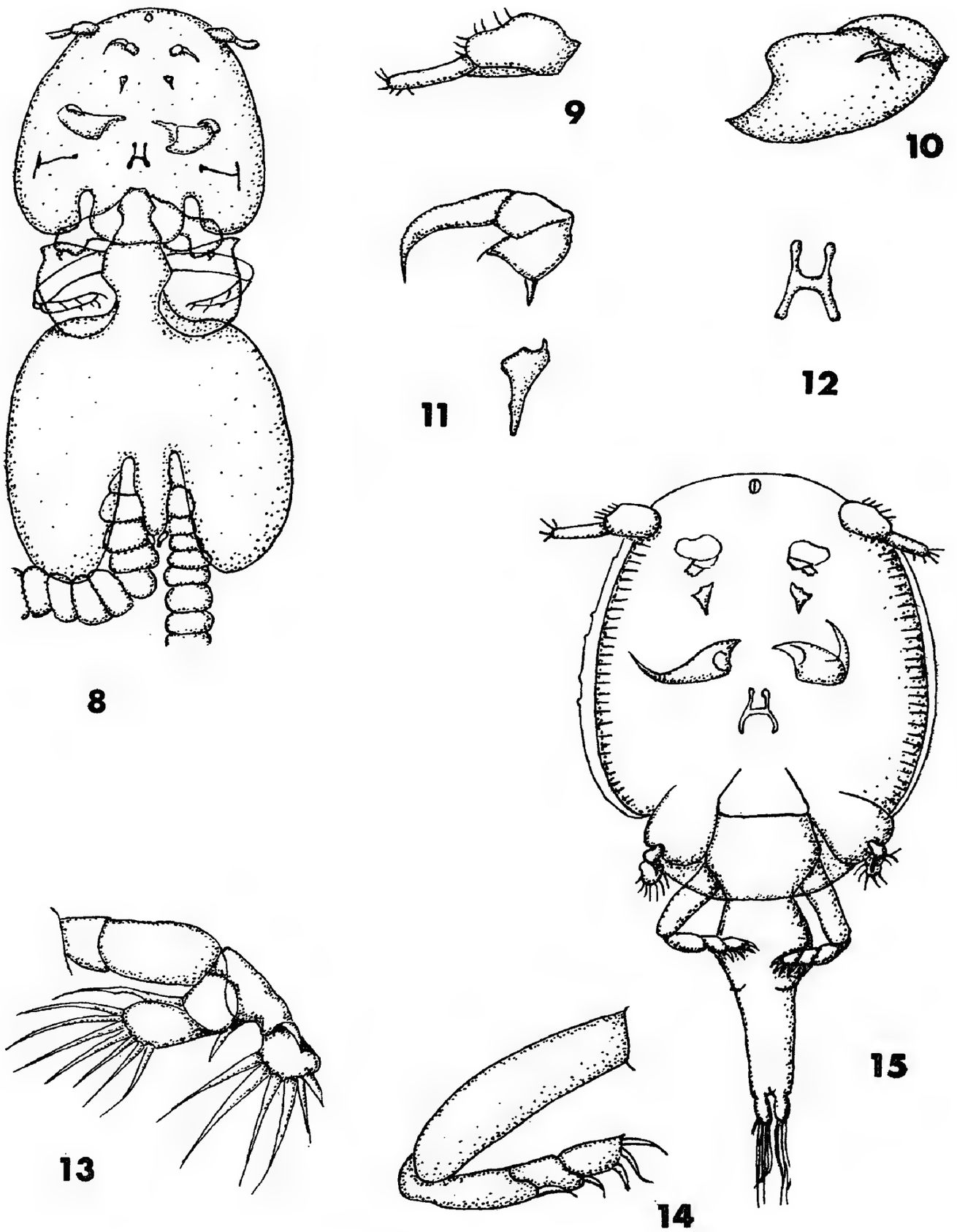
Family Pandaridae

Pandarus sinuatus Say, 1818

Eight collections from *Carcharhinus limbatus* (Müller and Henle), the spot-fin ground shark, three collections from *Sphyrna tiburo* (L.), the bonnet-head shark, and one collection from *Caranx hippos* (L.), the common jack. This is preeminently a shark parasite, and the dark brown females with their long brown egg strings can be recognized 20 feet away! They are on the surface, usually near the fins.

Perissopus communis Rathbun, 1887

Four collections from *Carcharhinus limbatus* (Müller and Henle), the spot-fin ground shark, one from *Scoliodon terrae-novae* (Richardson), the sharp-nosed shark, and one collection from a mullet, *Mugil sp.* This species, like *Pandarus sinuatus*, is a typical shark parasite, being found on the surface of the body and tail. The one from the mullet gills is probably an accidental attachment by a female dislodged from her proper host. We have noticed that they will cling to one's finger when detached from the shark.



FIGURES 8–15, *Paralebion pearsei*

Female:—8, ventral view; 9, antenna; 10, maxilliped; 11, second antenna and first maxilla; 12, furca; 13, second leg; 14, fourth leg. Male:—15, ventral view.

Family Anthosomidae

Lernanthropus brevoortiae Rathbun, 1887

One collection of a single female, in a membrane of presumably host tissue, from a porgy, probably *Pagrus sedecim* Ginsburg.

Lernanthropus gisleri van Beneden, 1852

Six collections, all from *Cynoscion nebulosus* (C & V), the spotted squeteague or speckled trout. This is a typical gill parasite of this host species and approximately half the fish of this species examined had it. Its brown color makes it conspicuous on the gills.

Lernanthropus longilamina Pearse, 1951

Two collections from *Chaetodipterus faber* (Broussonet), the spadefish. This is the third record of this species, which Pearse first described from the Bahamas and then from Port Aransas.

Lernanthropus paenulatus Wilson, 1922

One collection from *Sciaenops ocellata* (L.), the channel bass or redfish. This was a single male clinging to a gill filament.

Lernanthropus pomatomi Rathbun, 1887

One collection from *Cynoscion nebulosus* (C & V), the spotted squeteague or speckled trout, and one collection from *Pomatomus saltatrix* L., the bluefish. These were on the gills.

Lernanthropus pupa Burmeister, 1833

Three collections from *Chaetodipterus faber* (Broussonet), the spadefish, and one collection from *Cynoscion nebulosis* (C & V), the spotted squeteague or speckled trout, all from the gills.

Lernanthropus rathbuni Wilson, 1922

Two collections from *Elops saurus* L., the ten-pounder or locally the skipjack, and one collection given me from *Scoliodon terrae-novae* (Richardson), the sharp-nosed shark. The latter is a new and unexpected host and is regarded as accidental.

Family Eudactylinidae

Nemesis pallida Wilson, 1932

A single collection from *Carcharhinus limbatus* (Müller and Henle), the spot-fin ground shark. Five specimens, males and females, were on the gills.

Family Lernaeidae

Lernaeenicus longiventris Wilson, 1917

Six collections from *Caranx hippos* (L.), the common jack, and one collection from *Rachycentron canadus* (L.), the ling. These large, filamentous copepods generally occur on the pelvic and tail fins. It is perhaps the only copepod sportsmen appear to notice. Perhaps 25 per cent of these fish brought in by sportsmen are infested.

Family Pseudocycnidae

Lernaeolophus hemiramphi (Krøyer), 1863

A single collection from *Rachycentron canadus* (L.), the ling. This specimen, a female, appears to be the second specimen recorded.

Pseudocycnus buccatus Wilson, 1922

Ten collections, all from *Scomberomorus cavalla* C & V, the king mackerel. These are gill parasites and occur almost exclusively upon the gillets or most anterior demibranchs. They are often partly buried in the tissues and covered with a thin, structureless membrane. Probably 75 per cent of the mackerel examined were infested.

Family Lernaepodidae

Naobranchia lizae (Krøyer), 1863

Six collections from *Mugil cephalus* L., the striped mullet. This bizarre form, with its trematode-like body and curious wing-like processes clasping the gill filament, is in appearance one of the most attractive of the parasitic copepods.

Brachiella concava Wilson, 1933

A single collection of two females at the anterior gill opening of *Dasyatis americana* Hildebrand & Schroeder, the southern stingray. Wilson regarded this as rare. My limited experience suggests that anything on the stingray is rare!

Brachiella gulosa Wilson, 1915

Two collections from *Sciaenops ocellata* (L.), the redfish. One collection from immature hosts, the rat reds, had females with attached males.

Brachiella macrura Wilson, 1920

Three collections, all from *Pogonias cromis* (L.), the black drum. These occur on the gills and inside the opercular plate.

Brachiella rotunda Pearse, 1952

Four collections from *Prionotus scitulus* Jordan, the slender sea robin. This was described by Pearse (1952) from the same locality. It is a most attractive little form, Falstaffian with its fair, round "belly!"

Brachiella thynni Cuvier, 1830

Four collections, all from *Scomberomorus cavalla* C & V, the king mackerel. This large form "has been described or noticed by almost every writer on the parasitic copepods. . . . (Wilson, 1915)."

Clavellopsis strumosa (Brian) 1906

A single collection from *Archosargus probatocephalus* (Walbaum), the sheepshead, five females on the gills.

Discussion

Under the conditions of the study, it is not possible to indicate the prevalence of the infestation of fish hosts with the copepod parasites. It would be interesting and

valuable to study the incidence of copepod parasitism among some of the commoner marine fish, but such a problem would require facilities and time not yet available to the writer.

Twenty-three genera and 45 species of parasitic copepods are reported here, including 2 new species. Pearse (1952), collecting in the same area the preceding late spring and early summer, obtained 33 genera and 57 species of parasitic copepods (including 20 new species). The richness of the parasitic copepod fauna is indicated by the fact that only 17 species are common to the two lists. Compared with the author's Grand Isle, La., list (Causey, 1953), the Port Aransas list is much the longer:

	Grand Isle, La.	Port Aransas, Texas
Hosts	15 species of fish 2 species of invertebrates	32 species of fish
Parasitic copepods	15 genera and 24 species (2 new species)	23 genera and 45 species (2 new species)

Seventeen species of parasitic copepods are common to my Grand Isle, La., and Port Aransas, Texas, lists.

The difference between the two seems to be due to the greater opportunity to examine fish caught along the pier and jetty at Port Aransas, and it may be due in part to the fact that the waters are more saline. Literally hundreds of fish were available for examination practically every day of the month at Port Aransas, and of a greater variety (at least twice as many species) than at Grand Isle, La. I do not wish to give the impression that the survey at either place was exhaustive. More collecting at each place would certainly increase the listing. A more extended consideration of the parasitic copepods of the Gulf Coast will be dealt with in a forthcoming paper.

Summary

Twenty-three genera and 45 species of parasitic copepods from marine fishes are reported from Port Aransas, Texas, during the summer of 1952. Two new species, *Taeniacanthodes gunteri* and *Paralebion pearsei*, are described.

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The Relationship of the Bonnet Carré Spillway to Oyster Beds in Mississippi Sound and the "Louisiana Marsh," with a Report on the 1950 Opening[1]

By

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[1] This paper is a revision and extension of a mimeographed report, cited in the bibliography, wnich was previously submitted to the Corps of Engineers.

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INTRODUCTION

The Bonnet Carré Spillway was constructed by the Corps of Engineers, Department of the Army, as a part of the plan for control of floods in the alluvial valley of the lower Mississippi River. It lies in St. Charles Parish, Louisiana, thirty-three river miles above Canal Street of the City of New Orleans and was designed especially to protect New Orleans from Mississippi River floods and to lower river stages generally by diverting excess flood waters into Lake Pontchartrain. From there the water flows through Lake Borgne and Mississippi Sound into Chandeleur Sound and thence into the Gulf of Mexico. Construction of the spillway was started in 1929 and completed in 1931. The guide levees were completed in 1932. Figure 1 is a map of the area.

The length of the weir opening is 7,000 feet. Guide levees confine the flow to a width of 7,700 feet at the river and flare gradually to 12,400 feet wide at the lake shore, which is 5.7 miles away. The movable dam consists of 350 bays, each of which is 20 feet wide. These are opened as required. The designed capacity of the spillway discharge is 250,000 second feet of water. In actual operation the discharge is a little higher.

The Flood Control Act of Congress of 15 May 1928 and amendments provides that the spillway shall be opened whenever it is necessary to prevent the Carrollton (New Orleans) gage from exceeding 20 feet. The estimated frequency of operation is once in about 6 years. The spillway was opened in 1937, 1945, and 1950.

Because of the influence of fresh water on oyster beds, openings of the spillway have received considerable attention in recent years. The American oyster, *Crassostrea virginica* (Gmelin), is an estuarine animal which flourishes best in a mixture of fresh water and sea water. Butler (1949a) presented evidence that 6 parts per thousand salinity is a critical point and lower salinities are harmful. However, oysters can live at salinities lower than 6 *per mille* for a long time and field observations indicate that the critical point of low salinity is lower than Butler postulated. Since the flow of fresh water from land fluctuates, the oyster is often subjected to too much fresh water. This problem which has confronted the oyster industry around the lower Mississippi River for many years and the relation of the Bonnet Carré Spillway to oyster beds in Mississippi Sound is a part of the general problem.

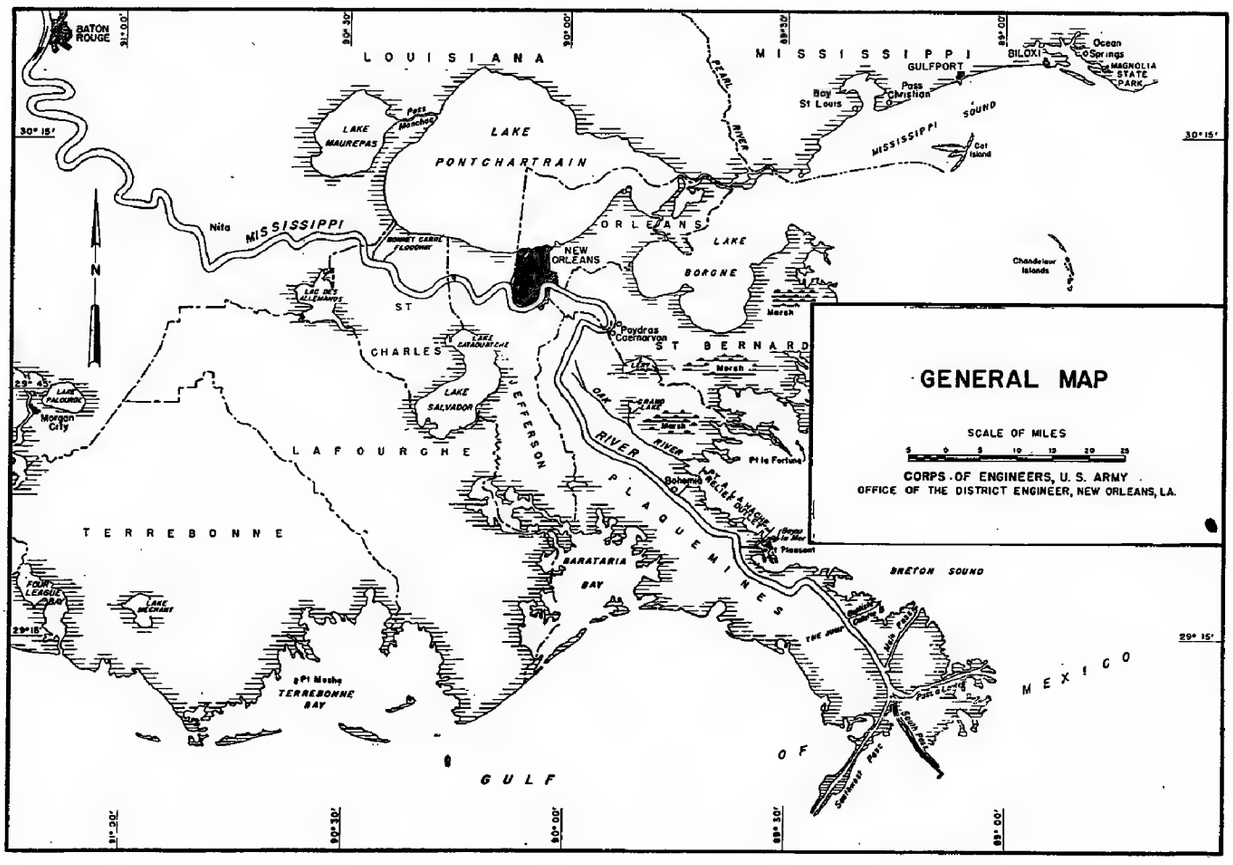
Since historic times and long before, oyster beds existed in the "Louisiana Marsh"[2] and Mississippi Sound. Before the white man settled Louisiana, the Mississippi River overflowed its banks every spring and flood waters entered the bays and sounds over a wide arc extending from Terrebonne Bay on the west to Lake Pontchartrain on the east. This subjected the oyster reefs of Louisiana and Mississippi to an annual or seasonal decrease in salinity during the first half of the year. Leveeing of the river was started by the French Colonials in 1717 and was begun in earnest in 1735. As the levee system grew and the distributaries of the river were cut off, the water was funneled out to the river's mouth in greater volume. The gradual seasonal fall in

[2] Most of the Louisiana coastal land is marsh. However, this name was specifically applied by Mississippi boatmen to the region of marshy islands and oyster bottoms of St. Bernard Parish, Louisiana. Mississippi towns are the closest ports. Cultivation is little practiced here, but the "Marsh" produces about half of the Louisiana oyster crop, and it is certainly one of the largest natural oyster production areas now remaining on earth.

salinity gave way in most bays to less annual change, interspersed with more violent fluctuations in some years when the levees broke, as they did quite often in the early days. Detailed effects of this historical change are unknown because no survey of the condition of oyster beds in early years was made. In addition, the early history of levees and crevasses is not good. However, there is considerable evidence of gradual historical increase of salinity in some oyster-producing areas. There is some indication that the region for oyster growth has slowly moved landward, with the increase in levees, and now lies closer to land than formerly. Oysters formerly grew around the Chandeleur Islands (Russell, 1936) and large dead reefs are present far out in Breton Sound where oysters no longer live.

Historically, the flow of fresh water from the Mississippi onto oyster bottoms may be divided into three stages. The first was a period of unrestricted flow extending from times unknown up to the period of extensive levee construction. It can be called the "prehistoric period." The second, which extended from about 1750 to 1927, can be called the "crevasse period." During this time any crevasse or break in levees on the east bank of the river from Baton Rouge to Caernarvon, Louisiana, let flood water through Lakes Pontchartrain or Borgne into Mississippi Sound. Breaks farther down the east bank let water flow into Breton Sound. Flood waters flowed through crevasses on the west bank into Barataria Bay. In the beginning the crevasse period probably resembled the prehistoric period because the levees were low and not continuous. Water flowed around them and breaks in the low levees were not greatly different from the former annual overflows. As the levee system grew in length and height, the crevasses became more violent.

The third stage may be called the "stable levee" period. After the great flood of 1927 all flood control was placed in the hands of the Corps of Engineers and the



Mississippi River Commission. Vast projects have brought a virtual end to crevasses and, although the conquest is never certain or final, some ascendancy over the river has been gained and the power of its destructive might has been curbed. A more detailed account of the history of the lower river and the changes effected has been given by Gunter (1952).

The Bonnet Carré Spillway is one part of the project to control the river. Crevasses have ceased and water flows through the spillway by the will of man rather than against his wishes; therefore much attention has been focused upon it. The opening of the spillway, so far as its effect on oyster beds is concerned, is not a new situation but is the same as that of a major crevasse, except that the spillway can be closed sooner. Thus it is similar to what has happened several times before in this area. There were crevasses at Bonnet Carré in 1849, 1859, 1867, and 1874. The 1874 crevasse was reputed to have raised the level of Lake Pontchartrain two feet. It was not repaired until 1882 and flood water flowed through it every year for eight years. The flow may have been anywhere from 70,000 to 225,000 second feet. (These calculations are made from figures in the office of the New Orleans District, Corps of Engineers.) No printed mention of damage to oysters from the Bonnet Carré crevasses has been found. In any case, the human population was smaller in those days and the oyster industry was not flourishing.

From 1849 to 1927 there were 38 crevasses from which water flowed into Lake Pontchartrain or Lake Borgne and thence into Mississippi Sound. This is an average of one every 2.1 years. The flow was not well recorded in most cases, but the average was probably around 65,000 second feet, with approximately a dozen flowing more than 100,000. Three crevasses flowed in excess of 300,000 second feet.

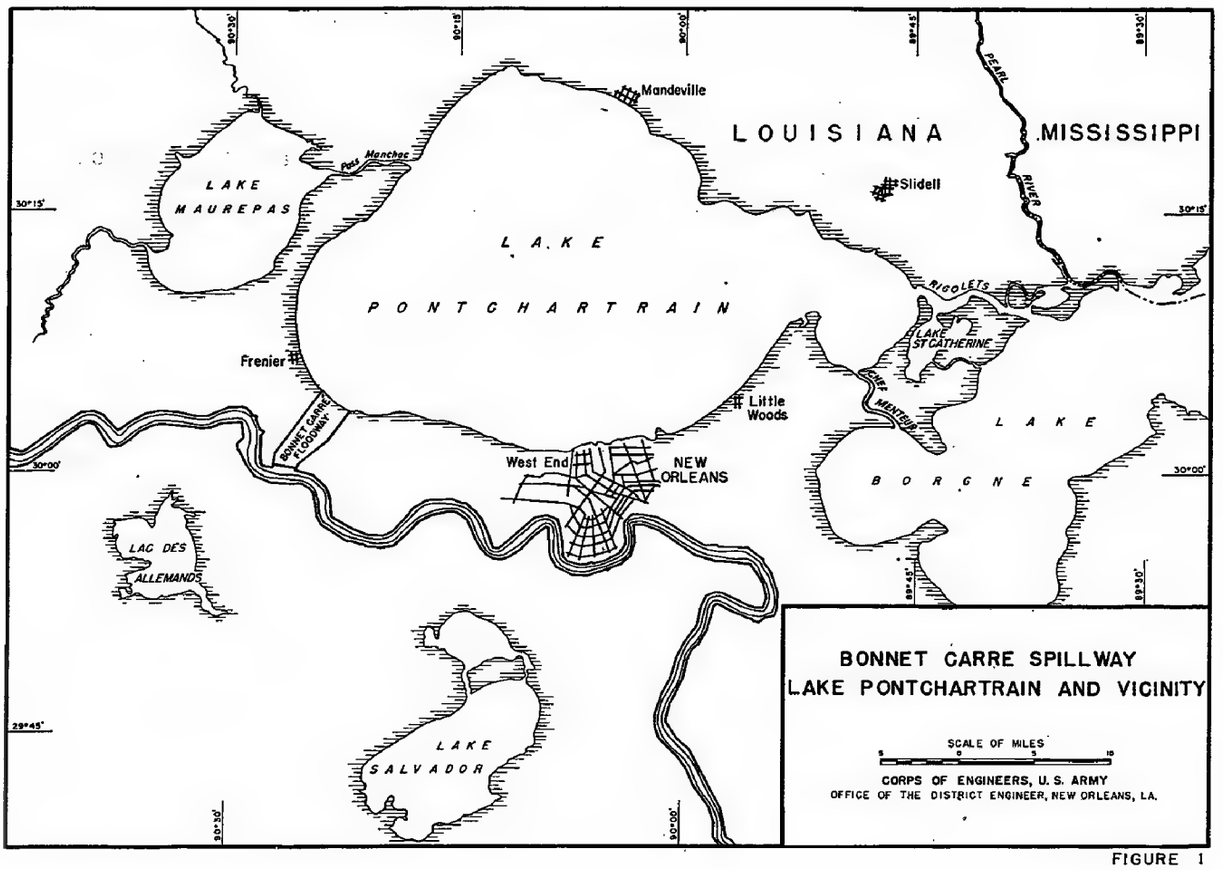


FIGURE 1

According to a report of the District Engineer (Hearings Comm. Flood Control, H. R. 3888, 79th Congress, 1946, p. 95) there were 19 major floods which discharged through crevasses into Lake Pontchartrain, Lake Borgne, and Breton Sound between 1849 and 1927. These were in the years 1849, 1851, 1858, 1859, 1863, 1871, 1874, 1882, 1884, 1890, 1892, 1893, 1897, 1899, 1903, 1912, 1920, 1922, and 1927.

The Oyster Commission of Louisiana was established in 1902 and reports on oyster conditions have been rendered since that time by the State. The period of overlap of these reports with the floods listed above covers 25 years and 5 major floods. During this time flood damage east of the river was mentioned 5 times, referring to 3 instances.

In the First Annual Report of the Oyster Commission of Louisiana (August 1902–January 1904) 1904, Mr. John Dymond, first chairman of the Commission, reported that the Nita Crevasse had killed every oyster in St. Bernard Parish. This crevasse broke in 1890 about 60 river miles below Baton Rouge. It was estimated to have flowed at the rate of 482,000 c.f.s. The water flowed into Lake Maurepas and Lake Pontchartrain.

The Fifth Biennial Report of the Department of Conservation (1920–22) said:

> The oyster crop is affected by drouth as well as an excess of rain. It is affected by tidal storms as well as by overflows, and it has suffered from all these conditions during the past few years.

The Sixth Biennial Report (1922–23) stated that:

> The oyster industry has been seriously affected by breaks in the levees in certain sections of the State—especially in the Louisiana Marsh. . . .

Both of these reports apparently refer to the levee break at Poydras Plantation in 1922, about fifteen miles below the City of New Orleans.

The Eighth Biennial Report (1926–28) said:

> . . . . the effect of the memorable flood of 1927 was felt over three large areas.

The Caernarvon Crevasse and the Bohemia Spillway were said to have caused great damage east of the river. It was estimated that a loss in excess of one-half of the 1927 crops was sustained in that area. The matter was mentioned again in the Ninth Biennial Report (1928–29), which said:

> . . . . the unprecedented floods of 1927, including the Caernarvon Crevasse, and the Bohemia Spillway destroyed approximately one-third of Louisiana's entire oyster crop.

The oyster industry of Louisiana beagn to flourish in 1902 at the time the Oyster Commission was established. The Commission later became the Division of Oysters and Water Bottoms in the Department of Conservation and its successor, the Department of Wild Life and Fisheries. A history of the Louisiana industry and production from 1880 to 1947, with a comparison to other Gulf States was given by Gunter (1949). Table I shows the average annual production of Mississippi and Louisiana by decades.

In summary, beds have been subject to the influence of flood waters during all of the recorded history of the oyster industry in Louisiana and Mississippi. From 1880 to 1927 these waters flowed through crevasses, the Baptiste Collette Gap (which attained considerable size by 1906) and the Bohemia Spillway or Pointe

à la Hache Relief Outlet, which was cut in 1924–25. Since 1927 there has been only one small break of the main line levees along the Mississippi River (above Port Allen, Louisiana, on the west bank in 1949) and the crevasses have had no influence from 1928 to 1950, inclusive. During this time flood waters affecting oyster beds have come through the Bonnet Carré Spillway, Baptiste Collette Gap, and the Bohemia Spillway. The last two affect waters adjacent to Breton Sound along the lower river. They are treated in Appendix I.

TABLE I

The average annual oyster production of the States of Mississippi and Louisiana by decades, as shown by statistics published by the U. S. Fish and Wildlife Service and its predecessors. During 1932, 1927, 1911 and all prior decades the oysters taken by Mississippi craft in Louisiana waters are not separated from Mississippi oysters. Figures are in barrels.

Years	Number of Years Reported	Annual Average Production Mississippi	Louisiana
1880–89	4	170,303	194,517
1890–99	2	220,468	276,826
1900–09	2	530,090	745,976
1910–19	2	189,589	974,309
1920–29	4	429,000	694,011
1930–39	8	342,423	657,960
1940–49	3	325,263	740,251

EFFECTS OF PREVIOUS SPILLWAY OPENINGS

The Bonnet Carré Spillway was opened in 1937, 1945, and 1950. Table II is a summary of the data on water flow. Figure 2 shows the same thing graphically. After entering Mississippi Sound most flood water flows out through the Cat Island Channel into Chandeleur Sound and thence into the Gulf of Mexico. Thus the fresh water affects only that part of Mississippi Sound lying west of a line from Cat Island to Pass Christian. A smaller portion of it works down through the Louisiana Marsh and reaches Chandeleur Sound by that route. Figure 3 is a map of the area.

TABLE II

Flow data on the openings of Bonnet Carré Spillway

Dates	1937 28 Jan.–16 Mar.	1945 23 Mar.–8 May	1950 10 Feb.–19 Mar.
Total days	48	57	38
No. bays opened	285	350	350
Max. observed c.f.s.	211,000	318,000	222,800
Av. observed c.f.s.	129,000	215,000	143,000
Total in acre-feet	12,400,000	24,500,000	10,900,000

a. THE 1937 OPENING

Viosca (1938) made some general observations on the effects of the 1937 spillway opening on marine life in Mississippi Sound. He noted the importance of the Pearl River in determining the salinity characteristics of Mississippi Sound and called attention to the nutrient salts brought into the Sound by the spillway. In 1937 he noted an oyster mortality of 10 per cent in Mississippi Sound which he

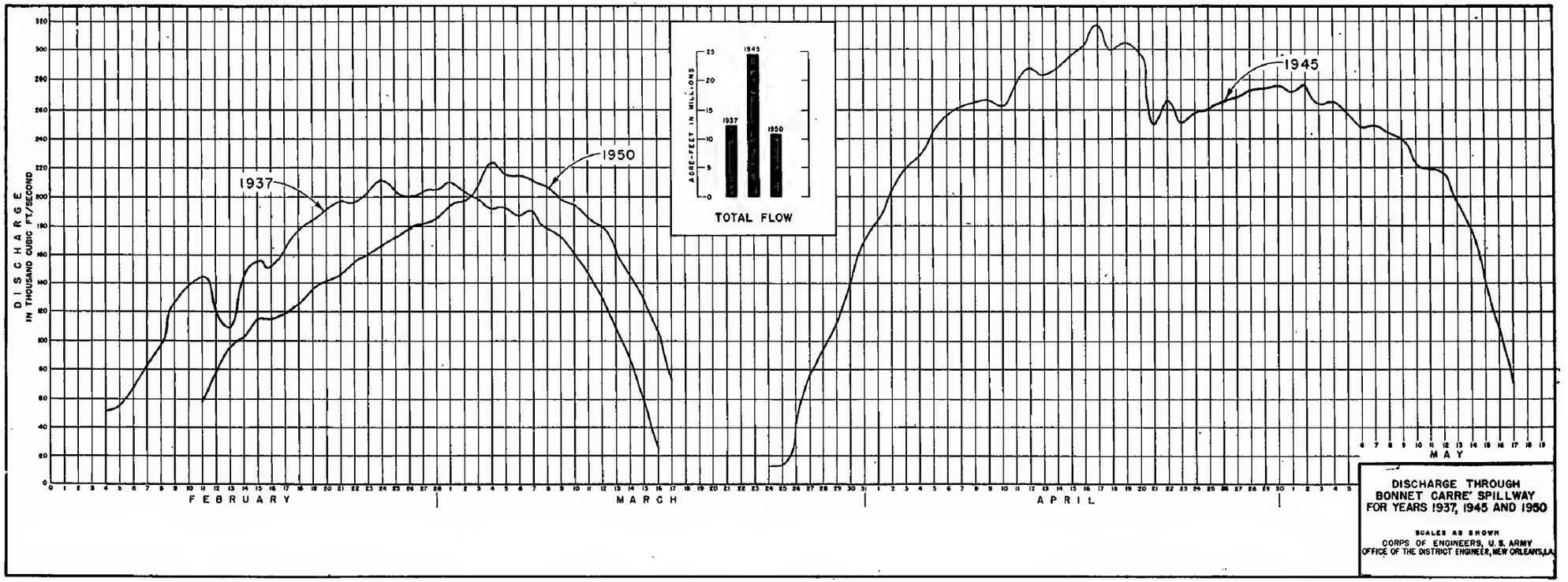

DISCHARGE
IN THOUSAND CUBIC FT./SECOND
1937
1950
1945
FEBRUARY
MARCH
APRIL
MAY
AGRE-FEEET IN MILLIONS
TOTAL FLOW
DISCHARGE THROUGH
BONNET CARRE' SPILLWAY
FOR YEARS 1937, 1945 AND 1950
SCALES AS SHOWN
CORPS OF ENGINEERS, U.S. ARMY
OFFICE OF THE DISTRICT ENGINEER, NEW ORLEANS, LA.

FIGURE 2

attributed to effects of the Pearl River. Viosca reported a beneficial effect of the 1937 opening of the Bonnet Carré Spillway and his words are quoted:

. . . . The general effect of the two floods (Pearl River and Bonnet Carré) on oysters in the sound was beneficial; and, although the oysters in the affected area lost their salty flavor, they fattened and grew considerably during the spring and made fine canning stock. . . .

In Mississippi Sound, where the spillway flow combined with that of the Pearl River flood, the muddy fresh water reached as far east as Gulfport for a short time and as far east as Cat Island Channel and Pass Christian for a longer period. Although the oysters on Telegraph and St. Joe Reefs were freshened, they are reported to have doubled in size during 2½ months after the opening of the spillway. The conchs, or oyster drills, on these reefs were killed by the fresh water. Speckled trout, driven eastward, were taken in unusually large quantities along the shores of Mississippi Sound during March and April. . . .

The effect of the spillway was, on the whole, very beneficial because of its fertilizing effect on the waters of Lakes Pontchartrain and Borgne, and Mississippi Sound. A biological cycle of organisms was started which was destined to materially increase the food supply in this area for some time. The plant growths were greatly stimulated, and associated animal life, such as scuds and grass shrimp, was found in great concentration. Plankton feeders, such as mullet, anchovies, menhaden, and shad were seen in great abundance everywhere, and in addition to the large crops of crawfish and river shrimp which served as an accessory food supply for a time, both species of salt-water shrimp thrived. The commercial shrimp crop taken in Lake Borgne and Mississippi Sound was the greatest since the shrimp trawl was introduced. . . .

In Mississippi Sound, the benefit to the oyster reefs persisted into the fall. There was a fine set of oysters which will develop as next year's crops; and all conchs were destroyed. Fish and shrimp were more plentiful than usual during the summer and fall.

There are other indications that the spillway opening of 1937 was beneficial to the oyster industry. The beds of St. Bernard Parish were affected by the Bonnet Carré Spillway. Table III shows the annual oyster production of this Parish, as well as

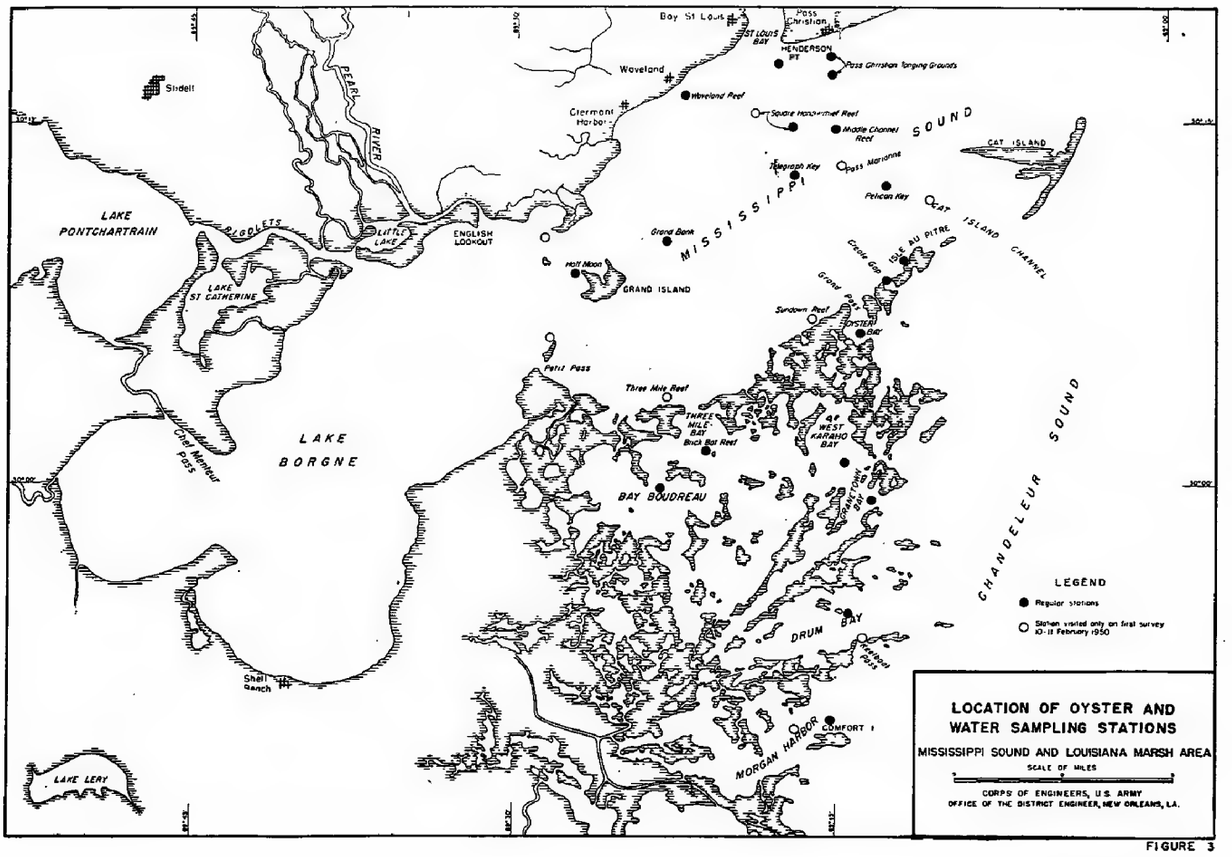


FIGURE 3

that of the State of Louisiana from 1932 to 1939. During 1937 St. Bernard Parish alone produced more oysters than the whole State did in the years 1932, 1933, 1935, 1936, and 1938. Oyster production of the State of Mississippi also seems to have been benefited and rose from 131,000 barrels in 1936 to 352,000 barrels in 1937.

TABLE III

Oyster production of St. Bernard Parish and the State of Louisiana from 1932 to 1939. Figures are in barrels.

Year	State Reports St. Bernard	State Reports State of Louisiana	Federal Reports State of Louisiana
1932	274,534	431,536	546,624
1933	394,691	616,816	(no report)
1934	725,809	943,228	686,585
1935	528,743	704,406	(no report)
1936	561,010	767,697	536,787
1937	786,618	1,087,176	1,220,828
1938	346,548	576,050	716,838
1939	647,585	864,874	871,847

During 1937 St. Bernard Parish and Plaquemines Parish, which also draws oysters from the Louisiana Marsh Area, produced about 92 per cent of all oysters gathered in the State. The production of Plaquemines Parish rose from 48,388 barrels in 1936 to 112,450 barrels in 1937. However, oysters from west of the river from beds affected by the Bohemia Outlet, also come into this Parish. Any beneficial effect of the Bonnet Carré operation would only explain part of production increase in Plaquemines.

The other two important oyster-producing parishes, Jefferson and Terrebonne, showed a decline of combined production from 145,424 and 141,067 barrels between 1936 and 1937. They lie west of the river and were not affected by flood waters.

Concerning oysters, J. N. McConnell reported in the Thirteenth Biennial Report of the Louisiana Department of Conservation (1936–37):

> . . . production for the years 1936 and 1937 has surpassed that of any two-year period in the history of our State.

He believed the increase was due to the annual shell-planting program "carried on by this Department," and the fact that people were eating more oysters the year round. The spillway was not mentioned.

Production declined in 1938, but this could scarcely be attributed to the spillway opening of the previous year. Fresh water mortalities always show up within a month and there is no delayed action. Furthermore, the decline also took place in other oyster producing areas not affected by the spillway (see Table III).

Due to the fact that the spillway was opened on 28 January, its influence on oyster beds in the Sound and the Louisiana Marsh lingered during most of 1937. Oystermen and dealers concerned with the Mississippi Sound area generally agreed that the 1937 spillway opening was beneficial. All observations and available information indicate that the effect of this opening was beneficial to marine life and that the fact was widely recognized.

b. The 1945 Opening

In contrast to the 1937 opening of the Bonnet Carré, the 1945 opening was generally reported to have caused considerable damage. No study of the oyster beds of Mississippi Sound was made between 1937 and 1945 until after the beds were reported to have been killed by water from the spillway, which was open from April 24 to May 17. During July, 1945, approximately two months after the spillway was closed, Dr. A. E. Hopkins, then Director of the Pensacola Laboratory of the U. S. Fish and Wildlife Service, made an examination of the area with officials of the Louisiana Department of Wild Life and Fisheries. No reports were published. Doctor Hopkins stated (Hearings Comm. Flood Control, H. R. 3888, 79th Congress, 1946, p. 95):

> Throughout this entire area on all of the major grounds, I found practically 100 percent mortality. In a few cases I found a few live oysters. They were in the neighborhood of Grand Pass, ...

These remarks apparently apply to Mississippi Sound proper. There seems to be little doubt that practically all oysters in the Sound west of Pass Christian were killed. The southwest half of this area, roughly speaking, belongs to the State of Louisiana. The only live reefs there are two seed beds. The northwest half of the area belongs to Mississippi and it contained the most oysters. It appears that in the Sound, Mississippi reefs suffered by far the greater damage. No State production figures are available. The Fish and Wildlife Service collected figures in pounds on Mississippi production for the years 1940, 1945, and 1948. Converted into barrels, the figures are 709,406, 82,875, and 409,000, respectively. The production for 1945 seems to have been only about 15 per cent of what it was in other years. Presumably the difference was due to flood damage. Unfortunately, there are no figures for 1944, 1946, and other years.

Officials of the Mississippi Seafoods Commission reported that in the fall of 1945 a good set of seed settled on shells of oysters killed the previous spring (Engle, 1948, p. 3).

The area of the "Louisiana Marsh" is somewhat different from the open Sound. McConnell *(op. cit.)* stated that after the spillway was opened, the water over the northern part of the area, including Bay Boudreau, West Karaho, Three Mile Bay, Oyster Bay, and Grand Pass, looked the same as river water and salinity tests showed it to be fresh. All oysters were reported to have been killed. McConnell's estimate was 8,000,000 barrels of oysters killed. The State of Louisiana produces around 800,000 barrels of oysters a year. The growth rate of oysters there is quite fast and even assuming a high annual natural mortality, the standing crop necessary for the annual production obtained is probably not as great as McConnell assumed. His estimate seems to be high. However, there is little doubt that practically all oysters in the northern part of the Louisiana Marsh were killed. Nevertheless, the spillway water did not reach the Louisiana beds in time to greatly interfere with the spring oyster season (January to April). This is shown in Table IV. This table shows the spring and fall production for St. Bernard and Plaquemines parishes and for the remainder of the State, as a whole, for the years before, during and after the first two spillway openings. The years 1948 and 1949 are included for com-

parison. This table was compiled by members of the staff of the Corps of Engineers, New Orleans District, from monthly production figures in the Department of Wild Life and Fisheries, through the courtesy of Mr. J. N. McConnell. The spring production for St. Bernard Parish for the years 1944, 1945, and 1946 was 285,064, 348,475,[3] and 194,693 barrels, respectively, being highest during the flood year. Data collected by the Corps of Engineers showed that lowest salinities did not reach the Rigolets (exit from Lake Pontchartrain, see fig. 3) until 15 May and Chef Menteur until 1 May. Because of that fact the 1945 spillway opening did not interfere with the 1945 spring oyster season in St. Bernard Parish. The State of Louisiana also permitted Mississippi boats to remove 34,000 barrels of oysters from these waters in May, probably because of the threat of oncoming flood waters. The fall season of that year showed a sharp reduction and there was a 44 per cent reduction in the spring season of the following year, 1946. However, the production was higher then than it was in 1949, which was not a flood year. In brief, there was about a 43 per cent reduction of oyster production in St. Bernard Parish in 1946 as compared to 1945. The production of this parish was 299,898 barrels in 1947, which was equal to the pre-flood year of 1944.

TABLE IV

The oyster production of St. Bernard and Plaquemines Parishes is compared to total Louisiana production by season for the years before, after and during spillway openings. The figures are in barrels

	Spring	Fall	Totals	Spring	Fall	Totals	Spring	Fall	Totals
		1936			1944			1948	
St. Bernard	555,280	5,730	561,010	285,064	13,601	299,665	203,659	53,151	256,801
Plaquemines	16,613	31,775	48,388	131,925	49,755	181,680	133,839	24,578	157,758
Totals	571,893	37,505	.....	416,989	64,356	.....	337,498	77,729	.....
Other Parishes	85,717	72,582	.....	101,162	51,796	.....	251,144	59,685	.....
		1937			1945			1949	
St. Bernard	769,158	17,460	786,618	348,475	14,601	299,665	203,659	53,151	256,801
Plaquemines	86,877	25,573	112,450	191,896	79,703	271,599	133,180	157,758	290,938
Totals	856,035	43,033	.....	540,371	80,292	.....	307,867	336,144	.....
Other Parishes	133,091	40,156	.....	316,678	44,257	.....	232,745	31,717	.....
		1938			1946				
St. Bernard	335,562	10,986	346,548	194,693	1,619	196,312	.....	.....	.....
Plaquemines	21,423	26,634	48,057	183,489	68,954	252,443	.....	.....	.....
Totals	356,985	37,620	.....	378,182	70,573	.....	.....	.....	.....
Other Parishes	94,300	60,343	.....	170,078	34,544	.....	.....	.....	.....

Flood damage effects were not apparent the second year after the Bonnet Carré Spillway was opened. Probably the flood waters killed oysters in the north end of the Marsh, while benefiting the oysters farther down by killing out conchs and parasites and bringing in nutrient salts. This in no way lessens the extent of the

[3] The State reports give 197,859 barrels as the total oyster production in St. Bernard Parish in 1945. A check of the original work sheets in the office of the Louisiana Department of Wild Life and Fisheries shows that in March 75,000 barrels were inadvertently left out of the final figure. In addition, most St. Bernard oysters were reported from Mississippi, in Mississippi barrels, which is 31.4 per cent larger than the Louisiana barrel. Addition of this corrective factor and the missing figures brought about the discrepancy between the reports published by the State and the figures given here.

catastrophe to the individual operators, who lost their holdings on leased ground. Fortunately, the chief area of private oyster grounds in Louisiana lies west of the river. Practically all production east of the river is from natural reefs.

It is clear from the table that Plaquemines Parish production was higher in both 1945 and 1946 than it was in 1944. This parish draws oysters from areas affected by the Bonnet Carré Spillway, the Bohemia Relief Outlet and Baptiste Collette Gap. There is no evidence of reduced production due to flood damage.

Table V gives the annual oyster production of the major oyster-producing parishes and that of the State of Louisiana from 1940 to 1949. During this time the parishes of St. Mary, Iberia, Vermilion, and Cameron produced around 84,000 barrels and they are not listed separately. The average production for the State was over a million barrels a year for the four years 1940 to 1943. The average was lower in the succeeding four years, running around 690,000 barrels a year. The break occurred between 1943 and 1944. There was a 31 per cent decline from one year to the next. It was considerable in the four main oyster-producing parishes, St. Bernard, Plaquemines, Jefferson, and Terrebonne. The First Biennial Report of the Department of Wild Life and Fisheries (1942–1945) gave the labor shortage and the effect of floods from the Bohemia Spillway as the cause of the decline in 1944. The Bohemia Spillway only affected Plaquemines waters. It had no effect in St. Bernard, Jefferson, and Terrebonne where production declines were also considerable. Some other cause than flood waters seems to be the cause of the decline in 1944.

TABLE V

The annual production of oysters by parishes from 1940 to 1949, as reported by the State of Louisiana. Figures are in barrels

Parish	Years									
	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949
Plaquemines	1,081,458	601,900	544,842	561,151	299,665	197,859	195,309	299,898	215,067	272,570
Plaquemines	122,370	137,853	282,635	210,497	181,680	275,682	220,881	135,078	210,318	272,731
Jefferson	44,569	74,368	70,015	86,336	49,713	34,711	18,970	20,872	20,421	24,674
Lafourche	5,486	15,590	23,583	14,811	17,860	14,160	7,098	22,519	44,287	56,779
Terrebonne	67,684	140,610	237,709	205,070	85,385	106,019	153,856	181,486	206,309	199,807
Others	12,870	7,486	10,176	———	———	———	25,017	1,406	———	———
Totals	1,081,458	977,807	1,178,960	1,077,865	634,303	628,431	621,130	661,259	696,402	826,740

THE 1950 OPENING OF BONNET CARRÉ SPILLWAY

a. Preliminary Investigations in the Area

On 19 September 1947 a severe hurricane struck the Gulf Coast, doing damage to oyster beds in Alabama, Mississippi, and Louisiana. It affected the area under consideration. During the month of November a survey of the oyster beds of the storm-struck region was made by Mr. James B. Engle of the U. S. Fish and Wildlife Service. He attempted to measure the density of oysters on the beds and took various other data which are valuable as a background to later events in the Mississippi Sound (Engle, 1948).

His chief findings were that damage to Mississippi reefs was heavy. His tables showed a mortality of 9 to 95 per cent in the area. The damage extended from Biloxi westward to the Louisiana line. Engle said:

The most severely affected portion was the inshore oyster beds from Bay St. Louis west to the State line. Most of the tonging reefs and planted bottom in the region were destroyed. Oysters reported to have been present were either killed or had disappeared. . . . . Some of the reefs, fortunately, are immediately reclaimable but other parts where mud was washed a foot or more deep over the reef probably will take years to recover.

The oyster reefs in the immediate vicinity of Pass Christian were damaged, but not seriously destroyed. Recently killed oysters of all sizes were represented among the mud-blackened boxes. No large oysters were available from the reefs at this time but many small ones were still there. This does not alleviate the present condition, but leaves some hope for a production of oysters within the next year or two.

Strangely enough, the offshore dredging areas suffered much less than the coastal tonging regions, but here again this situation offered no relief because the offshore oysters were mostly small and not ready to harvest due partly to the mortality of the major portion of the population in 1945 by the fresh water from the Bonnet Carré Spillway.

Concerning the Louisiana Marsh, Engle said:

There was some damage in the Marsh from about Karaho Bay northward. In the south at Eloi Bay, storm damage was not seen but most recent spat was dead.

The Eightieth Congress passed an appropriation for study of the area damaged by the Bonnet Carré Spillway and other flood waters in 1945. The work was carried out by Dr. Philip A. Butler in 1948 and 1949. His report (Butler, 1949) came out just before the 1950 spillway opening and it is a valuable commentary on the oyster situation in Mississippi Sound in the years immediately preceding the 1950 opening.

Butler did not study the Louisiana Marsh. He divided the western part of Mississippi Sound, from Cat Island westward, into two parts. He said the history of the reefs from 1945 to 1948 showed this to be a natural division. The separation was south from St. Louis Bay. He characterized them briefly as follows:

Area I. The ten major oyster producing reefs of the State of Mississippi lie in a 200 square mile section of Mississippi Sound, extending west from Cat Island to a line running due south from the town of Waveland. The southern part of this section includes natural reefs within the borders of the Louisiana marshes. This area experienced a 50 to 100 per cent mortality in the oyster population during the flood of 1945. The hurricane of 1947 caused additional damage which was primarily on the inshore shallow water reefs. In the spring of 1949, there was no evidence of abnormal mortality here but neither was there much new growth. The majority of oysters on these reefs are less than the market size of 3 inches. . . .

Area II. This section comprises approximately 100 square miles with many small natural oyster reefs and some private oyster bedding grounds in the westernmost part of the Mississippi Sound. It includes oyster bottoms under the jurisdiction of both Louisiana and Mississippi.

The oysters in this area are for the most part less than 2 inches in length and on many reefs there are only oyster spat less than a year old. This area suffered nearly 100 per cent mortality in 1945, and was severely damaged again by the hurricane in 1947 and in the early part of 1949 more than half of the remaining small population of oysters died. The large dead shells on some of these reefs carry a succession of scars left by small oysters. These scars are the attached shells of small oysters which have died. Most of the scars are an inch or less in length and frequently lie one on top of the other. This indicates that although young oysters have been setting here regularly in the past four seasons, they have nearly all died before reaching the age of one year. . . .

These facts were gathered in preliminary surveys and Butler listed among the problems raised, the reasons for poor growth of oysters in Area I and the reasons for the annual mortalities of oysters in Area II.

By the end of May, 1959, after a period of low salinities, the two areas were characterized as follows:

Area I. The different reefs in this area follow a certain similarity in pattern which permits a generalized statement concerning the suitability of this section for growing oysters during the first 6 months of 1949.

In this period the reefs suffered either a negligible mortality or that small amount which I should expect to find under the best conditions for oyster production. In May, all of the oysters were feeding, they had spawned from 25 to 50 per cent of their sex products and the oyster meats were typical of good quality oysters during a spawning season. But in all cases, new shell growth was limited to 5 mm. or less and on 5 out of 7 reefs the deposition of new shell material was just starting. Ordinarily, along the Gulf Coast, the period from February to May is one of the major growing seasons of the year. In these months, oysters at the Pensacola Laboratory increased more than 50 per cent in average length.

In my opinion, the environment for the period January through May 1949 in this area, while not detrimental to the point of killing the oysters, has been distinctly unfavorable.

Area II. The reefs studied in this section were without exception, seriously depleted in number of oysters and amount of clean cultch. Ninety-five per cent of the oysters present were less than 3 inches long; the shells were smooth and free of fouling organisms. It is characteristic of oysters exposed to excess fresh water to have smooth white shells which are not fouled by other commensal organisms. The oysters had deposited almost no new shell material. Although in May, the oysters had commenced feeding, there was little significant development of the gonads. With one exception, there was no set of 1949 oysters. Station 10, the easternmost reef in the area had received a heavy spat fall and showed the least mortality, 26 per cent, of any reefs in Area II. The remaining stations had recent mortalities ranging from 45 to 95 per cent of the small population still present. The reef bottoms varied from good to poor. Many showed the effects of the 1947 hurricane in having excess sand and soft mud.

The oysters in both Areas I and II are primarily on public reefs. The Louisiana Department of Wild Life and Fisheries and the Mississippi Seafoods Commission plant shells or seed oysters on their respective reefs, and, by controlling the oyster harvesting, maintain these reefs, for the benefit of the citizens. There are a few privately held leases for oyster breeding grounds on the western edge of Area II within the State of Louisiana.

Other remarks concerning mortality are worth quoting:

Mortality. The preliminary survey of the Mississippi Sound oyster areas affected by the 1945 flood showed, in the summer of 1948, that while there had been good annual sets of oysters there had been no survival of commercial importance. The hurricane of September, 1947, caused considerable mortality on some of the bars. In other areas having high mortalities this storm could not have been the direct cause. . . .

Survey of these bars in the first week of December, 1948 showed that a fair proportion of the 1947 spat had survived and that the mortality of the 1948 spat was less than 10 per cent. At this time salinities on the bars averaged 5 to 6.5 ppm. During December, however, precipitation in the region was quite general and resulted in a decline in the salinity. . . .

Butler evidently meant the salinities in parts per thousand (sometimes written *per mille* or *pro mille*), for 6 p.p.m. is less than average river water. He studied the mortalities of oysters in trays in this region. At 5 stations the accumulated mortality from 1 January to 1 June 1949 ranged from 46 to 95 per cent and averaged 60 per cent.

Butler reported that the water of this area in February, 1949, was fresh. It was muddy and had the characteristics of river water.

His findings in summary are given below:

Area I. The growth, mortality and condition of the oysters in the section of Mississippi Sound indicate that in early spring the salinity levels were minimal for the support of the populations. These conditions started to improve late in April and by the middle of May a normal environment for growth and reproduction was attained.

Area II. The growth, mortality and quality of oysters in the west end of Mississippi Sound indicate that this environment was extremely unfavorable. There was no evidence that internal or external parasites were present in sufficiently large numbers to affect the oysters seriously. The physical factors in the environment such as temperatures, turbidity and pH were within the range found in other localities where oysters thrive. Transplantation of these oysters to other areas demonstrated that there were no inherent factors to prevent normal growth and development. Finally, the evidence points to the conclusion that a low salinity level was the single important factor in causing the poor conditions which existed in the oyster population.

He recommended that Area II be used only as a seed bed when natural replacement takes place, the oysters being removed to better areas, and that no money be spent in rehabilitation. He then discussed the effects of the Pearl River drainage on Mississippi Sound. That point will be returned to later.

The above remarks have been quoted to show the following points: After the 1945 opening of the Bonnet Carré there was a good oyster set on Mississippi reefs in the fall. In 1947 the area was severely damaged by a hurricane. According to Butler, fresh water from the Pearl River was excessive each spring for three out of four years. In short, conditions were very poor for oysters in Mississippi Sound in all years between 1945 and 1950.

b. Other Investigations of the 1950 Opening

Essentially three studies of the 1950 opening were made. Dr. Butler continued his study and some observations were contributed by his colleague in the Fish and Wild Life Service, Mr. James B. Engle. The State of Louisiana carried on an investigation under Dr. H. Malcolm Owen. The writer carried on an investigation for the Corps of Engineers. The results of the other two investigations have been published. The Fish and Wildlife Service, under a publication date of March, 1950, was first with a paper entitled "The 1950 Opening of the Bonnet Carré Spillway—Its Effect on Oysters," which is remarkable for the fact that the data on which it was based were all collected before the spillway waters got out of Lake Pontchartrain and onto the oyster beds.[4] These and the continuing series of data were published by Owen and Walters (1950a, b) and can be considered in connection with those papers.

Butler and Engle (1950) said:

The discharge from the Pearl River alone during the past three out of four years has been sufficient to cause severe oyster mortalities.

The water in the entire area is now fresh enough to drink. Water temperatures are sufficiently high so that oysters are physiologically active. If this condition continues, we may expect a loss of the major portion of the small existing population within the next two months. In the first week of March, twenty-two days after the spillway was opened, the Mississippi River water had still not passed through Lake Pontchartrain to reach the oyster reefs in Mississippi Sound. From this fact it may be stated that the fresh water in Mississippi Sound has been derived from Lake Pontchartrain and from the Pearl River Basin and not from the Bonnet Carré Spillway. At the present time, the Bonnet Carré Spillway is being shut down and its over-flow is much less than capacity. It may be assumed, however, that the fresh water conditions in Mississippi Sound are going to continue for some weeks and that an adverse environment for oysters will exist there until flood stages on the Pearl River subside.

[4] Since these remarks were written, a more complete report by Butler (1952) was published.

Under the title of "What Spillway Really Did," Owen and Walters (1950), published results of the State of Louisiana investigation. They collected data on turbidity, salinity, temperatures, and oyster mortality and made aerial observations on the progress of river water through Lake Pontchartrain.

They showed that the river water did not start out of the Lake until 3 March, twenty-one days after the spillway was opened. They observed no sedimentation of the oyster beds. Salinity samples at 22 stations were taken. From 11 February to 17 February (before the river water got out of the Lake), they showed that Lake Borgne and the northern part of the Sound, from about Pass Christian westward, had a salinity of 3 parts per thousand or less. The remainder of the Sound had a salinity ranging from 6 to 12. From 6–11 March all stations in Mississippi Sound and Lake Borgne were found to have a salinity less than 2 *per mille*. They stated that the salinity began to rise again on 22 March, five days after closure of the spillway and gave a figure showing that on 6 April all parts of the Sound, except the western tip and a narrow band from Pass Christian west on the northern shore, had salinities between 6 and 11 parts per thousand. They said the bulk of Mississippi River water had not reached the Sound at that time, but the rise in salinity was still gradually progressing. They found that the fresh water had reduced the conch population. Mortality checks on the two important Louisiana reefs in the west of the Sound showed a progressive but low mortality at Grand Bank. A check on 3 March and 6 April gave 13.3 and 13.6 per cent mortality. Half Moon had an average 15.2 per cent mortality in three checks from 23 March to 6 April. They concluded:

> In 1950, because of the time of the year and relatively short exposure, the major reefs of Louisiana were not materially damaged but are expected to be benefited as a result [of] opening of the Bonnet Carré Spillway.

c. The Present Investigation

The writer made four surveys of the oyster reefs in Mississippi Sound and the Louisiana Marsh with Messrs. Jack Roy and W. E. Shell of the Corps of Engineers. The first one was made on 10–11 February. Captain Meco Filopich, Chief Inspector of the Mississippi Seafoods Commission, carried us to all important reefs in the area. These were selected as stations. They are all shown on the map, figure 3. From one to four dredge hauls were made at each station. The oysters were examined as to condition, taste, stage of sexual development, associates and commensals, recent growth, general size, and mortality. Temperatures and water samples were taken at each station. In the laboratory of the New Orleans District these samples were analyzed for dissolved solids, suspended solids, and chloride ion.

Certain stations were visited only once or twice and then abandoned because oysters were absent or uncommon and the stations were not of particular consequence. They are described in the Appendix. All stations are shown in figure 4.

Various stations for the collection of hydrographic data were set up as part of the Spillway Operation by the Corps of Engineers. These yielded information corollary to the present study and the data are given in tables in the Appendix.

1. Conditions on the Beds, 10–11 February

The first survey was in the nature of a reconnaissance. Several dredge hauls were made at each reef. Precise counts of large numbers of oysters were not made. A description of each reef is given in the Appendix. The various reefs in the area fell into groups, which can be described together.

The Pass Christian Tonging Ground, Henderson Point, Square Handkerchief, and Middle Channel Reef were prolific beds, with mostly seed or small oysters. They were sharp-edged and had been laying down much new shell. The oysters tasted fresh and their condition[5] ranged from poor to fair. All of them opened easily and lacked strength. Mortality seemed to be about 5 per cent on a basis of 150 oysters counted. Table VI shows that the salinity ranged from 4.4 to 8.9 *per mille*. These reefs will be referred to as the Mississippi inshore reefs.

At Telegraph Key the oysters tasted brackish. Young oysters were abundant and little market stock was present. This reef is treated with Pelican Key in the following pages because they were both close to the main channel and thus usually subjected to higher salinities. At Pelican Key the oysters were hard to open, their condition was excellent, they tasted salty and had no new shell growth. Many oyster borers or conchs, *Thais haemostoma*, were present and several were brought up with each dredge load. There was a considerable oyster mortality, apparently caused by the conchs. Many of these oysters were market size and the reef was not so prolific as the seed beds closer to shore. This was the only productive Mississippi reef in salty water at the time of the first survey. These two are called offshore reefs.

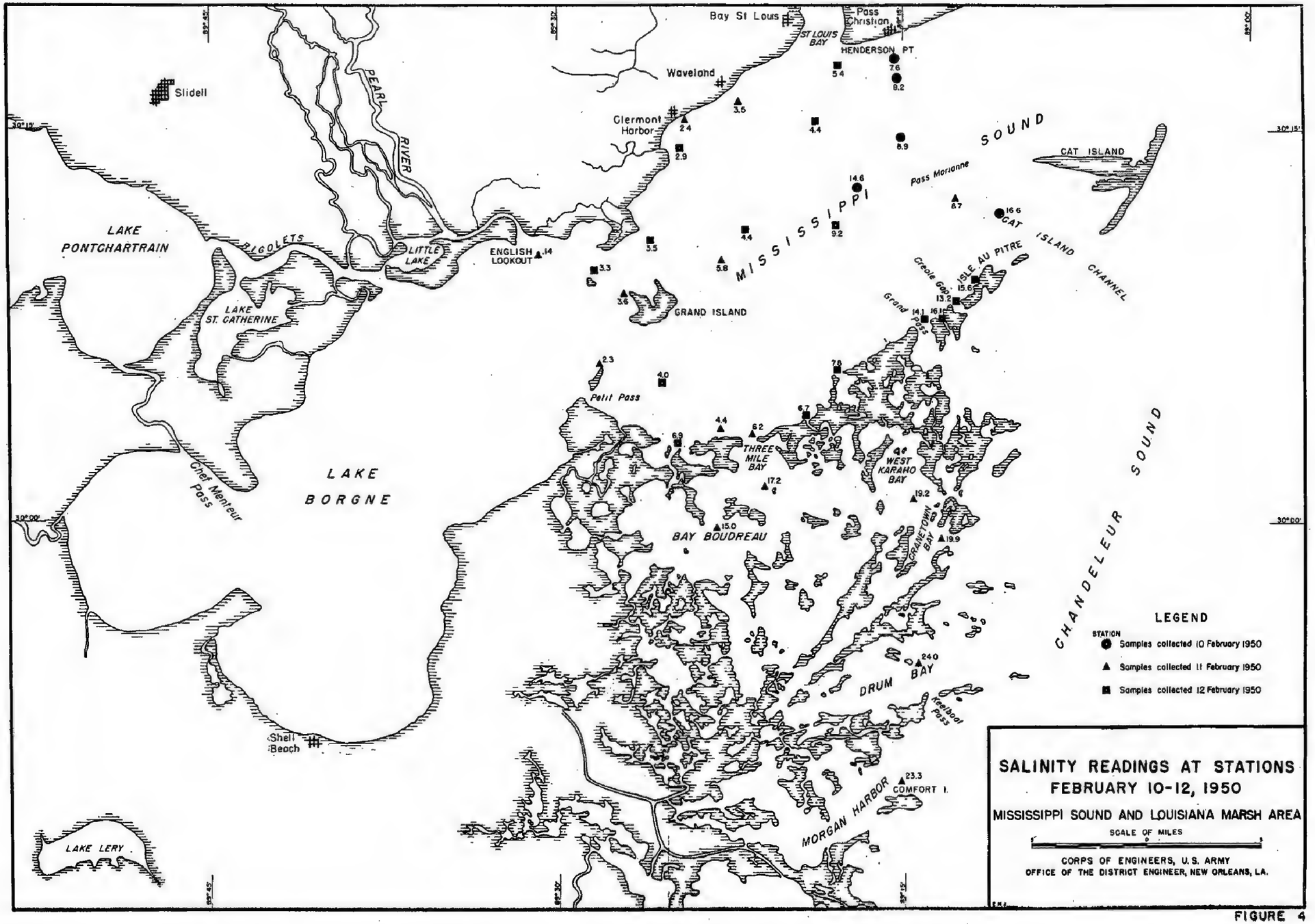
Grand Bank is a large seed bed in Louisiana, near the west end of the bay. Half Moon was a scattered, smaller and poorer reef, a little farther west. The oysters were white, rounded, clumped and sharp-edged. There were few commensals. The oysters tasted fresh and a few on Grand Bank were "milky" (maturing sexually). There was no recent mortality. Oysters at Petit Pass were in the same condition, except that they were very scarce. The salinities were 2.3 to 5.8 parts per thousand. An oyster boat was taking seed from Grand Bank at the time.

Two other Louisiana reefs in the Sound lie in salty water near the north end of the marsh. These are called offshore reefs and are treated as a unit with the two Mississippi reefs, Telegraph and Pelican Keys. The oysters were market size and not especially prolific. Conditions ranged from poor to excellent. Conchs were present and had caused considerable mortality. Some oysters had new shell. One ripe oyster was seen. The oysters tasted very salty. The salinity was 13.2 and 15.6 *per mille*.

Table VI gives the salinities at all stations on the examination dates. It should be consulted in connection with the description of the areas. Figure 4 shows the salinities at various locations on 10–11 February.

An examination of Table VI shows that oysters in the Marsh were in salinities ranging from 15.0 to 24.0 *per mille*. Many of them were market size and some were ripe. Condition ranged from poor to excellent. Mudworms and boring sponges were associated with these oysters. Barnacles and mussels were not abundant. Boring clams

[5] This refers to quality of the oyster meat. Glycogen in oyster tissues gives them a white or slightly creamy appearance. Oysters with considerable glycogen lose little juice when opened or cut, and are said to be "fat." A poor oyster is translucent and is commonly called a "water bag," which it is essentially. There are all stages in between. This determination of condition by appearance is subjective, but, with proper experience, it is an important field test.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Clermont Harbor
SOUND
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Pass Marianne
MISSISSIPPI
LAKE PONTCHARTRAIN
RIGOLETS
LITTLE LAKE
ENGLISH LOOKOUT
LAKE ST. CATHERINE
GRAND ISLAND
ISLE AU PITRE
Creole Gap
Grand Pass
CAT ISLAND CHANNEL
Pelit Pass
THREE MILE BAY
WEST KARAHO BAY
LAKE BORGNE
Chef Menteur Pass
BAY BOUDREAU
CRANETOWN BAY
CHANDELEUR SOUND
DRUM BAY
Keelboat Pass
Shell Beach
MORGAN HARBOR
COMFORT I.
LAKE LERY
LEGEND
STATION
Samples collected 10 February 1950
Samples collected 11 February 1950
Samples collected 12 February 1950
SALINITY READINGS AT STATIONS
FEBRUARY 10-12, 1950
MISSISSIPPI SOUND AND LOUISIANA MARSH AREA
SCALE OF MILES
CORPS OF ENGINEERS, U.S. ARMY
OFFICE OF THE DISTRICT ENGINEER, NEW ORLEANS, LA.

FIGURE 4

were prolific. The oysters tasted salty. At most places there was new shell growth, although there was not as much on the Marsh oysters as on those in the Sound. In the lower, more salty part of the Marsh, there were signs of conchs and at Keelboat Pass fresh conch eggs were taken. Stone crabs and blue crabs bearing eggs were also present. A hundred or more boats were working in this area. Infestation of the shells by boring clams, *Martesia*, was heavy. No excess mortalities were seen. In Drum Bay boxes with up to 40 perforations by boring clams were seen.

2. Conditions on the Beds, 14–15 March

An examination of the table will show that water all over the Sound had a salinity below 0.5 parts per thousand at this time. It ranged from 0.08 at Henderson Point to 0.35 at Isle au Pitre. This is veritably fresh water. All salinities were from bottom samples at an average depth of 8 to 10 feet. Even in Cat Island Channel, at a depth of 25 feet, the salinity was 0.16. All over the area, as far down in the Marsh as we went, the water was various shades of muddy brown.

Table VI

Salinities in Parts Per Thousand at the Stations in Mississippi Sound and in the Louisiana Marsh

	10–12 Feb.	14–15 Mar.	12–13 Apr.	24–25 July
Inshore Reefs, the Sound				
Pass Christian Tonging Reef				
Inside	7.57	.16	4.00	———
Outside	8.15	.15	1.65	20.79
Middle Channel Reef	8.87	.13	5.35	22.23
Square Handkerchief Reef	4.36	.11	4.00	18.98
Henderson Point Channel	5.44	.08	1.20	18.53
Waveland Reef	3.46	———	———	———
English Lookout	.14	———	———	———
Offshore Reefs, the Sound				
Telegraph Key	8.69	.11	4.63	23.50
Pelican Key	14.65	.17	11.22	24.40
Creole Gap	13.21	.30	11.04	25.75
Isle au Pitre	15.55	.35	11.94	26.20
Cat Island Channel	16.64	.16	———	———
Seed Reefs, the Sound				
Grand Bank	5.81	.12	2.77	20.79
Grand Island (Half Moon)	3.64	.12	.61	16.28
Petite Pass	2.29	———	———	———
Three Mile Reef	4.36	———	———	———
Louisiana Marsh Reefs				
Oyster Bay	———	.52	8.51	23.50
Brickbat Reef	17.18	.50	6.53	23.95
Bay Boudreau	15.01	———	7.16	20.34
West Karaho Bay	19.16	1.28	7.97	25.30
Cranetown Bay	19.88	1.67	9.78	26.65
Drum Bay	24.04	1.42	9.32	26.65
Morgan Harbor	23.31	2.58	6.71	26.65

The Mississippi reefs next to the northern shore had a surprisingly low mortality. The oysters were weak and poor. They all tasted fresh and were not feeding. Dying oysters were searched for but no gapers were seen. A count of boxes in a small typical sample showed 8 in 193 recently dead, a mortality of about 4.1 per cent.

On Telegraph and Pelican Keys and in Cat Island Channel the condition of the oysters ranged from fair to fat and some oysters were milky. The same thing held

true for Isle au Pitre and Creole Gap. These oysters had had a recent mortality of about 11.1 per cent, or 18 boxes out of 152 oysters. The oysters had no crystalline styles. Most of the large barnacles were dead while the small ones remained alive in patches.

At Half Moon and Grand Bank the oysters seemed to be in better condition than at Isle au Pitre. The mortality was 4 in 134 oysters or less than 3 per cent.

In the Marsh the oysters had all ripened considerably and were all fatter than during the previous month. No considerable mortality was noted. Ten boxes among 190 oysters were found, which is less than 6 per cent. A few dying conchs were seen, but no live ones were seen anywhere. The oysters in the Marsh were not feeding, but they were not weak. They had definitely fattened and ripened sexually since the first survey, in the face of a falling salinity. Only at one station, Brickbat Reef, were any gapers or dying oysters seen. The water was too shallow for adequate dredging and we were unable to get into Bay Boudreau. However, at Brickbat mortality seemed to be about one-fourth. This reef had been in salty water and seemed to have a higher mortality than the other reefs that had been in fresher water. Thus, it agreed with Isle au Pitre, Pelican Key, and Creole Gap in the Sound, which had been in salty water and seemed to have a slightly higher immediate mortality than other reefs when the fresh water did come.

3. Conditions on the Beds, 12–13 April

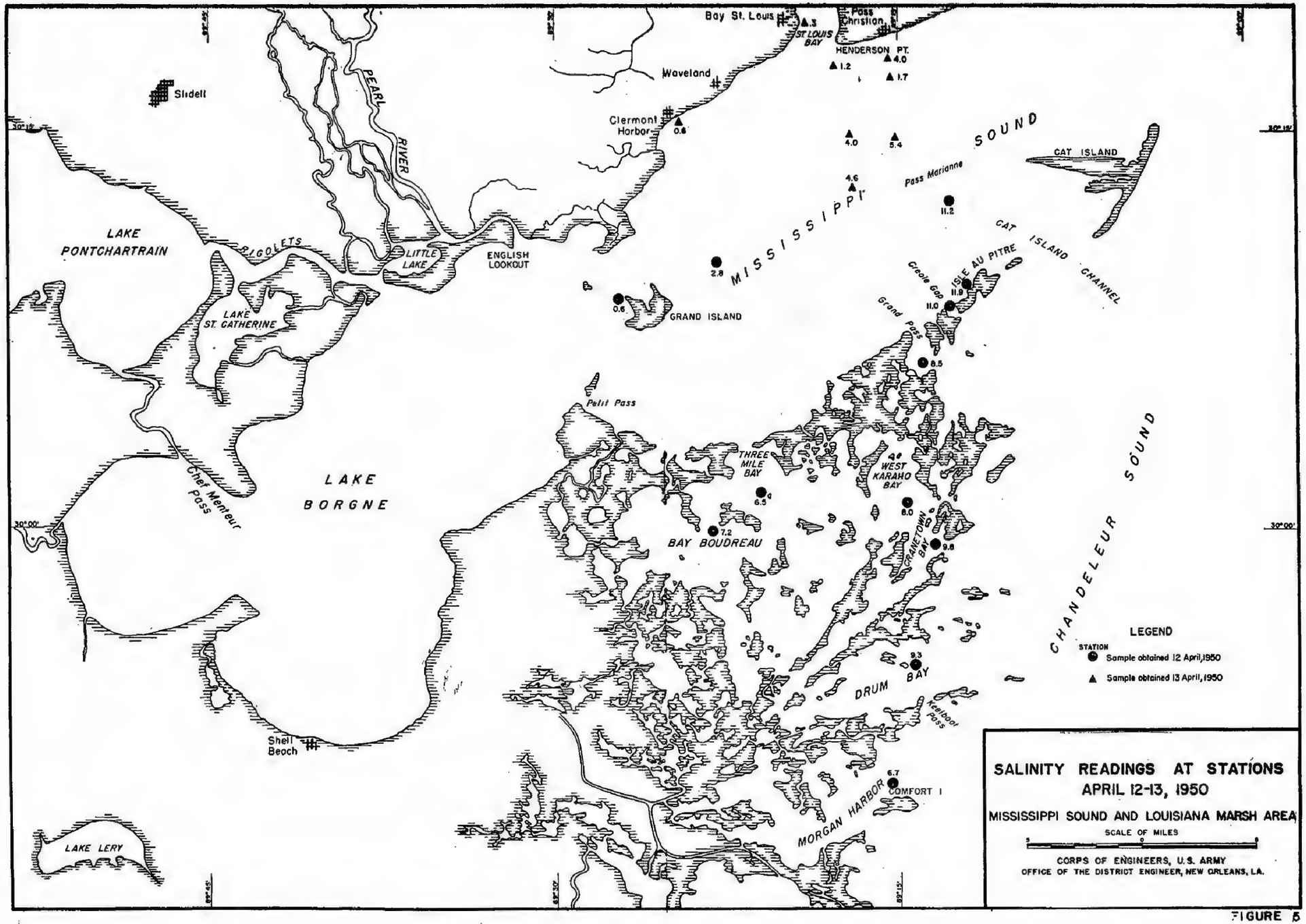
By 12–13 April salinities in the whole area had risen again. (See Table VI.) Only on the inshore reefs of Mississippi and on Grand Bank and Half Moon were the salinities lower than what is normally considered critical for oysters. Salinities at the stations are shown in figure 5. The average salinity on the Mississippi reefs, Henderson Point, Square Handkerchief, Tonging Grounds, and Middle Channel was 4.05 *per mille.* The mortality on these four reefs was 103 oysters out of 1,303 or 7.9 per cent.

At Creole Gap, Isle au Pitre, Pelican and Telegraph Keys (the reefs in the Sound which had been in saltier water at first) the mortality was 128 in 1,328 oysters or 9.8 per cent.

The two Louisiana reefs at the west end of the Sound had a mortality of 12.4 per cent on the basis of 685 oysters counted. This corresponds closely to Owen and Walters' (1950) figures of 14.0 per cent, taken twice at about the same period with a different method.

In the Marsh the average mortality was 5.2 per cent of the 2,217 oysters examined.

It should be stated here that all boring sponges, boring clams, and conchs were killed in the area of the study. None survived on the reefs examined, not even far down in the Marsh. Mud crabs, mudworms, and stone crabs did not seem to be affected. Many examinations for boring clams were made by cracking the oyster shells. At the time of the first survey, boring clam infestation was the heaviest I have ever seen. An adult oyster with no clam perforation through the shell to the inside was rare and oysters with 20 or more perforations were not uncommon. In April live clams were not found. They seem to be much more susceptible to low salinities than oysters are.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Clermont Harbor
SOUND
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MISSISSIPPI
CAT ISLAND CHANNEL
ISLE AU PITRE
Creole Gap
Grand Pass
LAKE PONTCHARTRAIN
RIGOLETS
LITTLE LAKE
ENGLISH LOOKOUT
LAKE ST. CATHERINE
GRAND ISLAND
Pelit Pass
THREE MILE BAY
WEST KARAHO BAY
LAKE BORGNE
Chef Menteur Pass
BAY BOUDREAU
CRANETOWN BAY
CHANDELEUR SOUND
DRUM BAY
Kenbook Pass
Shell Beach
MORGAN HARBOR
COMFORT I
LAKE LERY
LEGEND
STATION
Sample obtained 12 April, 1950
Sample obtained 13 April, 1950
SALINITY READINGS AT STATIONS
APRIL 12-13, 1950
MISSISSIPPI SOUND AND LOUISIANA MARSH AREA
SCALE OF MILES
CORPS OF ENGINEERS, U.S. ARMY
OFFICE OF THE DISTRICT ENGINEER, NEW ORLEANS, LA.

FIGURE 5

4. Conditions on the Beds, 24–25 July

The last survey was made on 24–25 July. In brief, three things were outstanding. Salinities at all stations were above 16 parts per thousand and averaged 22.9. They are shown in figure 6. No live conchs were seen. They had been largely wiped out over the whole area. Small boring clams, which had evidently set and bored in since April, were seen in the lower Marsh. All large ones were dead. Most oysters had ripened and were spawned out. The oysters were poor to medium in condition. Young oysters or spat were found over the whole area. There was an average of 51 spat on every ten oysters and shells over the whole area, including Grand Bank and the inshore Mississippi Reefs. During the first three examinations no spat were present. Therefore, spat were not included in mortality counts during the last survey. The recent mortality, on the basis of 5,060 oysters counted, was 6.9 per cent, with the exception of Telegraph and Pelican Keys. At those locations the recent mortalities were 34.6 per cent on the basis of 792 oysters examined. At Pelican Key over half the oysters were dead. Why this mortality developed on these two reefs after the salinity rose is unknown. There was no sign of parasitism or predation. These two reefs were in the area of Mississippi Sound with highest salinity before the fresh water came. Possibly they were subjected to too many extreme changes as th salinity returned to normal. They were in the region where considerable fluctuations could have taken place within a few hours as the tide and current changed. Nevertheless, this explanation is not satisfying.

Table VII shows the various areas with average mortalities and average salinities on the examination dates. The low salinities had been on the reefs only a week or so at the time of the 14–15 March survey. The mortalities found the next month reflect the damage caused by Mississippi River flood water. It ranged from 5.2 to 12.4 per cent. On the commercial reefs of Mississippi and Louisiana in Mississippi Sound the mortality was about 8.5 per cent. On the Louisiana seed bed (Grand Bank) the highest mortality of all, 12.4 per cent, was found. Fortunately, by nature a seed bed can have a high mortality with least harm. The best commercial reefs in the area, those of the Louisiana Marsh were practically untouched by mortality.

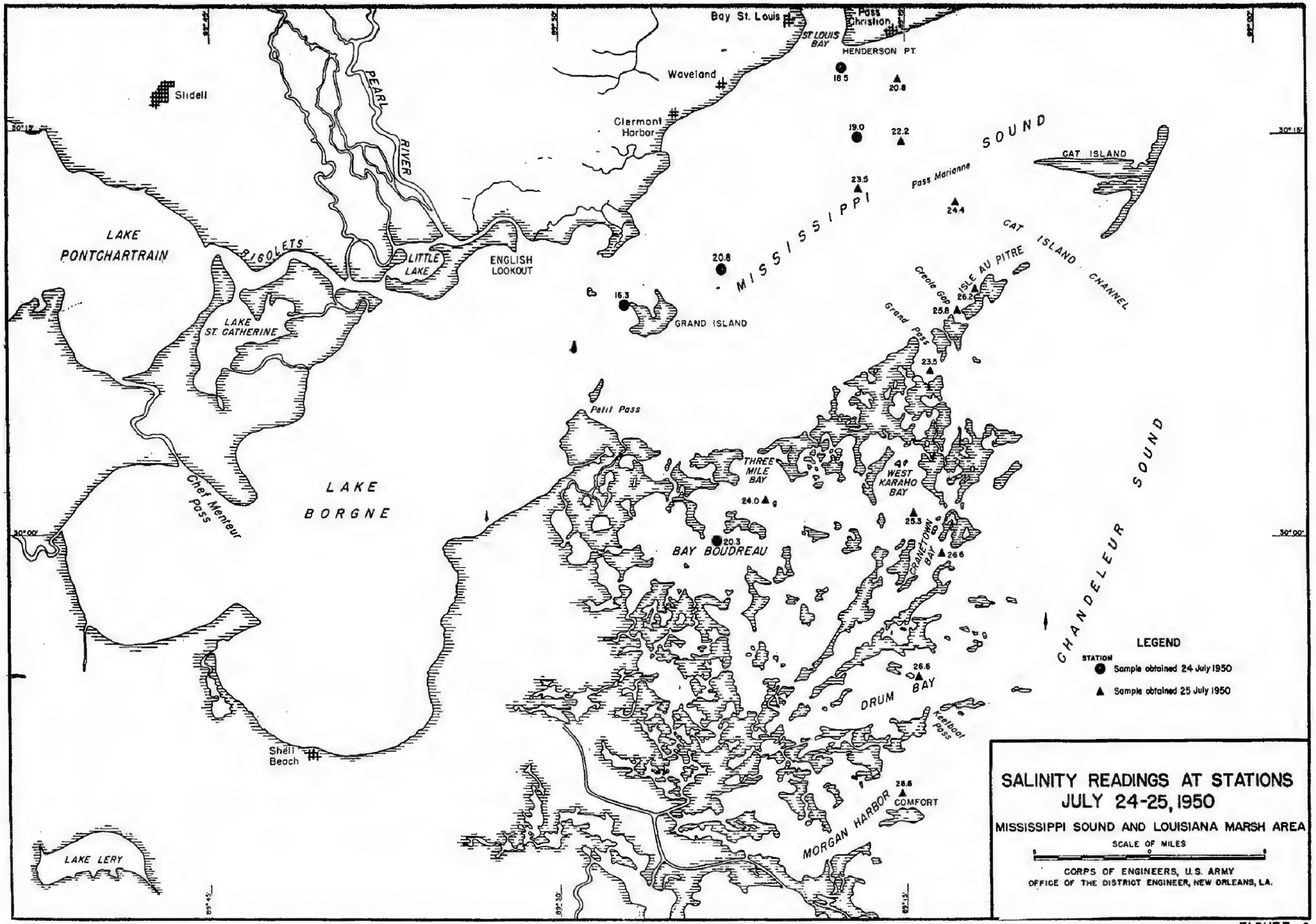
Table VII

Average Salinities and Mortalities for the Various Areas, discussed in the text

	No. Reefs	10–11 Feb. Ave. Sal.	10–11 Feb. Per Cent Mort. (est.)	14–15 Mar. Ave. Sal.	14–15 Mar. Per Cent Mort.	12–13 Apr. Ave. Sal.	12–13 Apr. Per Cent Mort.	24–25 July Ave. Sal.	24–25 July Per Cent Mort.
Inshore Reefs (Mississippi)	4	5.4	5.0	.13	4.1	3.2	7.9	20.1	9.4
Offshore Reefs (La. and Miss.)	4	13.8	....	0.22	11.1	9.7	9.8	25.0	9.5
Seed Beds (Western Sound, La.)	2	4.0	Little	.12	<3.0	1.7	12.4	18.5	2.9
"Marsh" Reefs	7	19.8	2	1.33	6.0*	8.0	5.2	24.7	6.0

* With the exception of Brickbat Reef.

Since oyster mortality was slight and nutrients were brought into the area by the river water and certain predators and injurious organisms were exterminated in the area, it is clear that the 1950 opening of the Bonnet Carré Spillway was beneficial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CRANETOWN BAY
CHANDELEUR SOUND
DRUM BAY
Ketlbot Pass
Shell Beach
MORGAN HARBOR
COMFORT
LAKE LERY
LEGEND
STATION
Sample obtained 24 July 1950
Sample obtained 25 July 1950
SALINITY READINGS AT STATIONS
JULY 24-25, 1950
MISSISSIPPI SOUND AND LOUISIANA MARSH AREA
SCALE OF MILES
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FIGURE 6

to the oyster beds in Mississippi Sound and the Louisiana Marsh. The implied dire possibilities of continuing "adverse conditions" by Butler and Engle (1950) did not come to pass. There seems to be nothing to add to the conclusion of Owen and Walters (1950a), that the opening was "highly beneficial" to Louisiana oyster beds except to extend it to cover Mississippi Reefs as well.

This is the most important immediate conclusion of this study. However, it does not cover all aspects of the spillway-oyster problem and some of them will be treated in following topics.

CONDITION OF OYSTER BEDS IN MISSISSIPPI SOUND IN 1951 AND 1952

General examinations of the oyster reefs in Mississippi Sound were made by the Corps of Engineers in 1951 and 1952 for the purpose of keeping in touch with the situation following the spillway opening. The first was made by Messrs. W. E. Shell, Jr., and Chas. Hassenboehler, April 19–May 1, 1951. The following remarks, quoted verbatim from their report, is a valuable record of oyster conditions in the area:

2. Inshore reefs of the State of Mississippi: All inshore reefs were open to oyster fishermen during the 1950–51 season. Employees of the Seafood Commission reported very heavy working of all these oyster beds. Maximum weight of a dredge in Mississippi is limited to 90 pounds and all beds were found solid and in a fairly clean condition.

a. Pass Christian Tonging Ground: The oysters on this reef were from ½ to 2 inches long, milky, in good condition, strong and slightly salty. They had been feeding but there was very little evidence of recent growth. There were no new boxes in the 200 oysters counted. The only parasites found were barnacles and boring clams. 4 boring clams was the highest count in any one valve. This is a clean hard reef.

b. Middle Channel Reef: The oysters on this reef were ½ to 2½ inches long, milky, in good condition, fairly strong and slightly salty. They had been feeding but there was no recent growth. There were only a few boring clams. Only one new box was found among the 200 oysters counted and it was buried in the mud.

c. Square Handkerchief Reef: Very few of these oysters were longer than 1 inch. They were slightly salty, milky, strong and in good condition. They had been feeding and some new shell had been added. There were a few mud blisters and many barnacles. No other parasites were found. One new box was found among the two hundred oysters counted.

d. Henderson Point: Oysters on this reef were ½ to 2 inches long, slightly salty, strong and in good condition. Barnacles were the only parasites found. They had been feeding and there was a little new shell. No new boxes were found.

3. Offshore reefs of the State of Mississippi: These two reefs, Pelican Key and Telegraph Key will be described together. At these two reefs 34.6 percent recent mortality was found in July 1950 (Page 33 of Gunter's report). Captain De Silvey of the "Uranus," Mississippi Seafood Commission, reported that an inspection made by his crew in September 1950 found almost 100 percent of the oysters were dead. He contributed the mortality to high salinity and warm condition of the water. No oysters were harvested during the 1950–51 season. The high mortality reported was verified by the number of large boxes which were held together by small oysters and the fact that only six large oysters were found in 200 at Pelican Key and none at Telegraph Key. All other oysters were less than 1 inch long. They were salty, milky, strong and in good condition. Twelve new boxes were found at Pelican Key and one at Telegraph Key. The oysters had been feeding. There was no recent growth. One conch was found at Pelican Key and none at Telegraph Key. There were a few boring clams and many barnacles at both reefs. Captain De Silvey reported a good set of spat on the old boxes in October 1950 accounting for the small oysters found.

4. Reefs along north of Louisiana marsh: These reefs were all opened to dredging during the 1950–51 season. They have been damaged by heavy dredging with the exception of Oyster Bay which is a privately leased area.

a. Isle au Pitre: These oysters were from ½ to 2 inches long, salty, milky, strong and in good condition. They have been feeding but there was no recent growth. Six new boxes were found among the 200 oysters counted. Four conchs were found. There were a few boring clams and many barnacles.

b. Creole Gap: These oysters were from ½ to 4 inches long, salty, milky, of medium strength, and in good condition. A few barnacles and boring clams were present. The oysters had been feeding. There had been no recent growth. Two new boxes were found in the 200 oysters counted.

c. Oyster Bay: This is a leased reef, and is clean and apparently well kept. Most of the oysters were from 1 to 3 inches long and in good condition. They were salty, strong and milky. They had been feeding but there was no recent growth. There were no new boxes. The oysters were covered with barnacles. There were a few boring clams. Mud worms were found but no mud blisters.

a. Grand Bank: This reef was heavily dredged for seed during the 1950–51 season. The oysters were from ½ to 1½ inches long, fresh, strong, milky and in good condition. They had been feeding and there has been a little recent growth. One new box was found in 200 oysters counted. There were a few boring clams and many barnacles. Mud worms were present but no blisters were found.

b. Half Moon: This reef was small but very hard. Most of the oysters were less than 1 inch long. They were fresh, milky, strong and in good condition. They had been feeding and there was a little recent growth. Nine new boxes were found in the 200 oysters counted. There were many barnacles and a few boring clams. Mud worms were present but no blisters were found.

6. All the oyster beds in Mississippi Sound between Half Moon Island and Pass Christian are in very good condition. Additional related data are given in the following tables.

RESULTS OF WATER ANALYSES

30 April and 1 May 1951

Station	Chlorine Cl- p.p.m.	Dissolved Solids p.p.m.	Suspended Solids p.p.m.	Temperature Degrees C	pH
		30 April and 1 May 1951			
Chef Menteur	1,200	2,514	115	26	7.18
Rigolets	350	690	272	25	6.97
Pearl River	23	50	26	23	6.65
St. Louis Bay	2,300	4,518	113	26	7.15
		1 May 1951			
Oyster Beds					
Pass Christian	3,100	6,352	155	25	7.35
Middle Channel	3,900	8,316	46	25	7.40
Square Handkerchief	3,375	7,014	150	26	7.75
Henderson Point	3,625	7,492	35	25	7.50
Telegraph Key	5,500	10,502	52	26	7.60
Pelican Key	6,300	13,934	32	25	7.73
Isle au Pitre	7,800	16,710	133	25	7.63
Creole Gap	8,800	19,960	114	25	7.82
Oyster Bay	7,800	17,340	343	26	7.63
Grand Bank	3,400	6,682	158	25	7.62
Half Moon	2,200	4,554	159	25	7.42

From this report it is clear that the general salinity had declined since July, 1951, but not to critical levels. Both market and seed beds were worked heavily during the 1950–51 season and possibly had been overworked. The peculiar mortality noted at Telegraph Key and Pelican Reef in July, 1950, seems to have progressed to almost 100

per cent kill of the market oysters. Mortality over the remainder of the reefs was low. A few conchs had returned to one salt water reef, Isle au Pitre.

On May 20, 1952, Mr. W. E. Shell made another examination of beds of the area and the following remarks are quoted from his report:

3. Inshore reefs of the State of Mississippi: No reefs in the State of Mississippi were open to oyster fishermen during 1951–1952 season.

a. Pass Christian Tonging Ground: Captain De Silvey reported considerable damage to the inshore grounds from silt which settled on them during the construction of beaches along the seawall by hydraulic dredge boats. They are reported to have recovered from this damage. The outside tonging reef was examined on this inspection and found hard and in good clean condition. The oysters were from ½ to 3 inches long, salty, medium fat and strong. Three new boxes were found in 200 oysters counted. The oysters were feeding but growth was slow. Some were milky and others spawned out; 14 spat were found on 10 oyster shells. There were a few barnacles and boring clams and no conchs, mudworms or sponges, however, one large cluster of shells covered with conch eggs was found.

b. Middle Channel Reef: This reef was clean and hard. There were many old boxes. The oysters were ½ to 3 inches long, medium fat and strong. Ten new boxes were found in 200 oysters counted. The oysters were feeding but growth was slow. They were almost spawned out and 18 spat were found on 10 shells. There were a few barnacles and boring clams. No evidence of conchs, mudworms or sponges was found.

c. Pass Marianne: This reef was hard and clean. There was a ratio of about 1 old box to 3 large oysters. Oysters were from ½ to 3½ inches long, salty, fat and strong. Six new boxes were found in 200 oysters counted. There was no evidence of feeding and growth was very slow. They were about ½ spawned out and 14 spat were found on 10 shells. There were very few barnacles and boring clams. No evidence of conchs, mudworms or sponges was found.

d. Square Handkerchief Reef: This is a large reef and two drags were made, one on the north and south sides. The oysters were about the same except the north side is cleaner. Only the south drag was counted. Fourteen new boxes were found in 200 oysters. The oysters were from ½ to 3 inches long, salty and in fair condition. They were feeding but growth was slow. They were about ½ spawned out and 12 spat were found on 10 shells. There were a few mudworms, barnacles and many boring clams and mussels. No evidence of conchs or sponges was found. This reef is being built larger to the west by moving shells from offshore reefs where the oysters are being killed.

e. Henderson Point: This reef was clean and hard. The oysters were ½ to 3 inches long, salty, fat and strong. They were feeding and growth was fair. They were about ½ spawned out but no spat were found. There were 6 new boxes in 200 oysters counted. There were a few mudworms, barnacles and boring clams. No evidence of conchs or sponges was found.

4. Offshore reefs of the State of Mississippi:

a. Pelican Key: One full dredge of shells were examined and only 5 oysters found. There were also 8 small new boxes. Four of these oysters were ½ inch long and one was about 2 inches long. They were in good condition and milky but had not been feeding and no growth was apparent. No spat were found. There were 12 small conchs, a few mudworms, a few boring clams and many barnacles. There was no evidence of sponges. The reef was hard and clean. Operations have not been started to move these shells.

b. Telegraph Key: Three drags were made on this reef. Of 200 oysters in the first dredge load 19 new boxes were found. All oysters were 1 inch long or less. They were salty, fat, strong, had been feeding and growth was good. They were milky and 10 spat were found on 10 shells. Fifty-seven conchs and 3 shells covered with conch eggs were found in the three dredge loads. There were a few mudworms, barnacles, and boring clams and no sponges. The Mississippi Seafood Commission is moving these shells and small oysters to the west end of Square Handkerchief Reef to increase the length of that reef where fresh water is usually available. Captain De Silvey reported one barrel of conchs collected from 150 barrels of shells during moving operations. This was not an effort to remove all conchs but just those which were seen by the men under normal dredging and unloading of the shells.

5. Reefs north of Louisiana Marsh:

a. Isle au Pitre: This reef was heavily dredged during the 1951–1952 season. It was muddy and soft. There were only four live oysters in one full dredge load. Several 2 to 4 inch new boxes and many small ones were found. There were many old boxes. The four oysters found were salty and in good condition. They were milky and one spat found on ten shells. Forty-nine conchs and one large cluster of shells covered with conch eggs were found. There were a few barnacles and boring clams.

b. Creole Gap: This area is a leased bedding ground in good shape. Oysters are from ½ to 4 inches long, mostly large. There were 9 new boxes in 200 oysters counted. The oysters were salty, fat and strong. They were about ½ spawned out and 10 spat were found on 10 shells. They were feeding and growth was fair. Twenty conchs were found and a stake 3 inches in diameter covered solid a length of 5 feet with conch eggs, was dragged out by the dredge. There were a few mudworms and barnacles and several boring clams.

c. Oyster Bay: This is a leased bedding ground in good condition except some soft muddy spots. The oysters are ½ to 4 inches long, mostly large. There were 6 new boxes in 200 oysters counted. The oysters were salty, fat and strong. They were feeding and growth was fair. They were milky and 3 spat were found on 10 oyster shells. Two conchs were found. There were a few mudworms and barnacles and many boring clams.

6. Louisiana Seed Reefs:

a. Grand Bank: This reef was heavily dredged for seed during the 1951–1952 season. It is still in good condition and the oysters were ½ to 2½ inches long. They were salty, fat, strong and in good condition. They were feeding and growth is fast. They were milky and 3 spat were found on 10 shells. About 25 conch eggs were found on one shell. There were a few mudworms and barnacles and many boring clams.

b. Half Moon: This reef is small and hard but has increased in size and quality of oysters since last year. It was dredged for seed during the 1951–1952 season. The oysters were from ½ to 2½ inches long. They were salty, fat, strong and in good condition. They were feeding and the growth was fast. They were milky and 2 spat were found on 10 shells. There were a few mudworms and barnacles and several boring clams.

7. The Mississippi Seafood Commission has obtained the services of Dr. A. E. Hopkins as a consultant biologist to study the oyster reefs of that State. This action was probably prompted by the severe losses on offshore reefs. In the State of Mississippi, Pelican and Telegraph Keys were destroyed in 1950 and 1951. . . . Telegraph Key only has a few very small seed left at present which would soon be destroyed if they were not being moved. Isle au Pitre reef in Louisiana has been destroyed this year and it is probable that the conchs will severely damage Creole Gap and Oyster Bay.

RESULTS OF WATER ANALYSIS

20 May 1952

Station	Chlorine cl p.p.m.	Dissolved solids p.p.m.	Temp. Degrees C
St. Louis Bay	7,900	16,814	-----
Pearl River	700	1,468	-----
Rigolets	4,800	10,236	-----
Chef Menteur	4,000	8,200	-----
Oyster Beds			
Pass Christian	12,250	26,740	24.3
Middle Channel	12,750	32,000	24.6
Pass Marianne	12,750	30,992	24.2
Square Handkerchief(s)	10,400	27,544	25.5
Square Handkerchief(n)	10,000	21,674	25.3
Henderson Point	9,000	20,042	25.3
Telegraph Key (S)	12,375	19,026	24.9
Telegraph Key (N)	11,500	21,162	24.8
Pelican Key	12,750	28,788	24.8
Isle au Pitre	12,250	26.810	24.7
Creole Gap	11,750	26,812	24.5
Grand Bank	10,000	25,094	24.7
Half Moon	9,000	26,558	24.6

Heavy mortality previously seen on the Mississippi offshore reefs struck nearby Louisiana reefs. Conchs had also invaded these reefs in large numbers, as well as becoming more abundant on Louisiana reefs north of the "Marsh". They had reached as far in as the Louisiana seed reef, Grand Bank. It appears that following a non-destructive spillway opening this predator may be killed all over the area, but it will reinvade in force by the second year afterward. Salinities were considerably higher than they were a year before, and in general the mortality was higher.

GENERAL AND THEORETICAL CONSIDERATIONS

Certain effects of the Mississippi flood waters and some other factors should be considered in connection with the spillway-oyster problem.

a. Determination of Oyster Mortalities

The determination of oyster mortality must always be understood to be a reasonable estimate. Only when there is complete mortality over a wide area, can it be assumed that the observer's estimate is completely accurate on a percentage basis.

The ordinary method of estimating mortality is to count the recently dead oysters. Oyster shells are held together by a hinge ligament. This elastic substance causes the two valves to stand apart or gape open when the oyster is dead. Oyster meats disappear quickly and the remaining hinged shells are commonly called "boxes". These boxes will hold together for a few weeks or months. Shells of recently dead oysters remain white or shiny on the inside for only a few days, the time depending on the season and rate of fouling. After a little time barnacles, other oysters and various other sessile organisms settle on the white shell, obscuring its lustre. Whether a box is new or old is a matter of judgment of the observer. Since some boxes will hold together several months, or until the shells are well eroded, it does not seem proper to include them all in estimations of recent mortalities. However, they were included in the above estimates, with very rare exceptions when the shells had a very old, eroded appearance. This method tends to set recent mortality at a slightly higher rate than it actually is. This is somewhat offset by the fact that not all boxes are recovered or found. For this reason some investigators attempt to get more accurate estimates by placing oysters in trays. This subjects the oysters to different conditions. It protects them from some predators and associates and causes others to gather in greater numbers, but the method is useful in areas where reefs are absent and oysters are scattered. Boxes which are moved or scattered about are not lost from a large reef and an adequate sample will recover most of them. Those that are not recovered must be set off against the changed condition of tray oysters in comparing the two methods.

Normal mortality on a reef seems to be about two to four per cent a month. It should be held in mind that any method, if repeated over and over in the same way, is valuable for comparison from one time to another. Oysters grow and die side by side at the same time and thus the total volume will hold steady or even increase while a quite perceptible mortality is taking place.

b. Predators and Commensals

Several marine organisms live on and in oyster shells. Barnacles and mussels have life histories quite similar to oysters and they attach to oyster shells and strain the

water for food. Mortality of mussels was not observed in this study. However, large numbers of barnacles were killed and it was mostly the young or small ones that survived. Boring clams, boring sponges and mudworms bore into oyster shells. They force the oysters to grow thick shells and weaken them by perforating their shells. Infestation from boring clams was extremely heavy over the whole area and infestation of sponges was heavy in some places. All sponges and clams were killed in the area in 1950, so far as observation went. However, some clams must have survived, at least in the nearby areas, for the July examination showed small clams in the oysters. Mudworms did not seem to be damaged by the fresh water. There has been some disagreement about the extent to which these organisms can harm oysters, but they are probably injurious to some extent.

The oyster borer, *Thais,* seemed to be eliminated in this area by the fresh water. Unpublished experiments of the writer show that these animals die at salinities between 10.0 and 8.0 parts per thousand. The borer is an important enemy of the oyster. It takes a considerable toll every year and occasionally it becomes abundant enough to virtually exterminate oyster reefs in localized areas. There are several known instances on the Gulf Coast.

The recently discovered oyster parasite, known as *Dermocystidium marinum,* has been associated with oyster mortalities on the Gulf Coast (Mackin, 1951). This organism is most abundant in waters of high salinity and presumably would have been considerably diminished in the Sound and Marsh in 1950.

In summary, fresh water killed out or greatly lowered the incidence of boring sponges, boring clams and oyster borers and inferentially it can be assumed that it did the same to the microscopic parasite, *Dermocystidium.* This is another aspect of spillway openings that is always beneficial.

c. Sedimentation and Turbidity

Most sediment in the spillway water is dropped in the floodway and Lake Pontchartrain. Some calculations of sediment loss in the floodway have been made. Approximately 63 per cent of the sediment load was dropped in the floodway in 1950. An average of 90 readings taken at the spillway showed 1,068 p.p.m. sediment, while at lake side the sediment load was 398 p.p.m., a loss of 670 p.p.m. Table VIII shows estimated deposits in the floodway for the three openings. This material stayed in the floodway and was lost so far as immediate effect on marine waters was concerned. As a matter of fact the floodway silts up with every opening and tends to choke its own flow. For that reason the Engineers do not like to open the spillway more often than is absolutely necessary.

Table VIII

Amount of Water Flow and Sediment deposited in the Bonnet Carré Floodway

Year	Period of Operation Days	Total Discharge Acre-Feet	Average Depth of Fill-Ft.	Total Fill Cu. Yds.
1937	48	12,400,000	0.89	10,200,000
1945	57	24,500,000	1.12	12,500,000
1950	38	10,900,000	0.45	5,000,000

Velocities of flood water drop almost to zero a few miles out in Lake Pontchartrain and all of the load but the finest particles, which remain in suspension indefinitely,

fall out. Such a sediment load change, however, leaves the appearance of the water largely unchanged. The water still has a brown or muddy appearance, but it cannot deposit large quantities of mud anywhere. It does not muddy or cover the whole lake bottom, which is 640 square miles in extent. Instead, the sediment settles out in an underwater delta fan at the mouth of the floodway, a section of about 30 square miles or about 5 per cent of the lake bottom. These considerations should be held in mind in weighing the statements about silting and destruction of the natural environment in Lake Pontchartrain. There is no proof that this environment is hurt.

Sediment falling out in Lake Pontchartrain may be redistributed later, for there is some evidence (Price, 1947) of a direct relation between width and depth of salt water bays on the Gulf Coast because effective scour is caused by wave action. Wave action depends on wind sweep and thus the width of the water body. Whether or not this sediment is redistributed later, it is removed from consideration as an effective agent on the oyster beds at the time of spillway openings.

Oysters will bury themselves in about two weeks time in their own feces and pseudofeces, if they are in still water, as has been shown by unpublished experiments of Dr. E. J. Lund carried out at this laboratory. The feces are essentially ropes of sediment bound together by mucous. Since this lumpy, mucous-bound material is harder to move than ordinary loose sediment, oysters living in areas where they will not bury themselves are not bothered by ordinary sediment. That seemed to be the case in Mississippi Sound where all reefs were clean and free of mud. Although river water could be seen all over Lake Borgne, Mississippi Sound and the Marsh, and far out into Chandeleur Sound, no sign of sedimentation on the oyster reefs was seen. Butler and Engle (1950) and Owen and Walters (1950a) made the same observation. The latter workers measured turbidity by passage of light. The Corps of Engineers collected data on the sediment load in parts per million. They are given in the Appendix. In neither case was there any particular correlation with salinity or distance from Lake Pontchartrain, but turbidity did rise with the influx of flood water. The amount of turbidity in these waters is correlated with wind velocity and wave action, or that is to say turbulence of the Sound, more than anything else.

d. Nutrient Salts

Fifty-two analyses of Mississippi River water by the New Orleans Water and Sewerage Board in 1905 and 1906 showed a nitrate content of 2.5 parts per million. Silicate was given as 11 parts per million.

One analysis of water coming through the Bonnet Carré Spillway in 1950 was made by the Corps of Engineers. It showed that the amount of nutrients were: nitrates 0.4 p.p.m., phosphates 1.25 p.p.m., organic nitrogen 2.1 p.p.m. On that basis there were 5,925 tons of nitrates, 18,517 tons of phosphates and 31,108 tons of organic nitrogen dumped in the waters of Louisiana and Mississippi by the spillway. However, it seems likely that the phosphate determination was over-estimated or the sample was abnormally high. In any case, it is easy to see why Viosca (1938) observed fattening of oysters and an increase in marine life in general in Mississippi Sound after the 1937 spillway opening. Therefore, a spillway opening always has a beneficial aspect, although it may kill oysters at inshore locations. This is probably the reason why the production of St. Bernard Parish held up so well in 1946 and 1947 after large numbers of oysters were killed there in 1945.

e. Salinity

The common American oyster has become accustomed to estuarine life where it undergoes wide fluctuations of turbidity and salinity. Oysters can survive a salinity as low as 2.0 per thousand for about a month at low temperatures. In fact, they can survive in fresh water for several days. They apparently accomplish this by closing the shell tightly and living anaerobically, which is the same way they survive in air. Under these circumstances it is likely that they utilize glycogen by reducing it. The ability to live for extended periods without oxygen is one of the adaptations of the oyster to live a little longer or cling tenaciously to life when covered by mud, exposed to air or exposed to fresh water. Thus, if conditions reverse themselves in a week or so, many oysters will survive. Since the ability to live with the shell shut tight is closely connected with the glycogen reserve, the survival rate will depend upon the previous condition of the oyster or, as it has been called, the fatness or strength. Likewise, it depends on the length of exposure and the temperature of the water, because rates of physiological processes are slower at lower temperatures. In other words, oysters may survive dangerously low salinities by beating a physiological retreat and walling themselves off from all environmental effects except those of temperature.

The winter of 1949–50 was extremely mild along the Gulf Coast. The January and February temperatures were above 20° C. many times. The spring, however, was cool and prolonged and average temperatures from February to April were lower than in January in the Mississippi Sound region. This is shown in Table IX, which is a summary of Weather Bureau observations at the town of Bay St. Louis on the Sound. The fact that the spring was cool was probably fortunate for the oysters exposed to the low salinities.

Table IX

Summary of Air Temperature Data at Bay St. Louis, Mississippi

1949	Average	High	Low	Departure from Normal
January	65.2	78	37	+12.5
February	60.6	79	36	+ 5.7
March	57.0	78	35	— 4.7
April	64.9	81	39	— 2.8
May	77.2	90	62	+ 2.7

On the Gulf Coast oysters become fat during the low temperature months (Gunter, 1942). Glycogen analyses were not made, but general observation showed quite clearly that oysters in Mississippi Sound and the Louisiana Marsh "fattened" considerably between 11 February and 13 March. Yet, at the time of the March examinations all oysters were in salinities much lower than the optimum range. They had no crystalline styles and were apparently not feeding on that date. This leads to the conclusion that the low extremes of salinity came upon the oysters not long before 13 March. It had not been upon them long enough to reduce their fatness.

The development of sexual products proceeded from February to March. This was in the face of a falling salinity and a slightly falling temperature. In February a few ripening oysters were seen in the lower Marsh. In March sexually ripening oysters were found everywhere except on the inshore Mississippi Reefs.

There is another fact to be considered in connection with the 1950 mortalities in the region. Butler showed conclusively that, for three or four years preceding the 1950 spillway opening, the oysters in Mississippi Sound had been subjected to very low salinities. This means that acclimation to these conditions and a weeding out of individual oysters most susceptible to low salinity had taken place in the immediately preceding years. Probably this situation was a factor in holding 1950 mortalities low.

The fact that larger barnacles were killed while younger ones survived is a matter of some significance as a general relation of animals to salinity of their environment. The young of motile marine animals are more prone to enter low salinities than their elders and there is some experimental evidence that the young of certain fish survive low salinity better than larger specimens.

Initially, mortality from fresh water was higher on reefs not previously subjected to low salinities. In these areas, however, the salinity returned towards normal most quickly, thereby probably preventing further mortality, and the highest mortality for the month following the flood developed on the most inward reefs, which were subjected to lowest salinity the greatest length of time. The first was due presumably to quick change of salinity and the latter due to long continued low salinity. The combined mortalities for March and April show that the most inward reefs, Grand Bank and Half Moon, and the reefs in saltiest water suffered the highest and almost equivalent mortalities. The inshore Mississippi reefs, which had previously been subjected to low salinities, also received the brunt of fresh water which, however, did not remain quite so long as on inmost reefs; these and the Marsh reefs, which were not subjected to lowest salinities were the least affected.

These observations depend upon the statistical validity of the simple counts of mortality. Over 12,000 oysters were counted in all, the figures at each place being given in the text. The previously mentioned comparison with Owen and Walter's data indicates that as comparative data from time to time, the counts may have been accurate within about 2 per cent. Although the average mortalities for the two months (March and April) combined were not greatly different anywhere, being about 6–10 per cent, the abrupt changes were on the Louisiana inmost reefs and the Mississippi reefs in saltier water. These changes were in the neighborhood of 8 to 9 per cent.

These results are explicable on the basis of three factors concerned with low salinity mortality. These are the minimum salinity obtained, time of exposure, and previous salinity regime. The last factor is related to the rate of salinity change. When it is remembered that mortality is also probably related to the water temperature and the fatness or condition of the oysters, which both are related to the time of the year, then it is seen that low salinity mortality of oysters is not a simple thing. And there is no reason to suppose that it less complicated for any other organism.

f. Significance of the Pearl River

Viosca (1938) first called attention to the importance of the Pearl River in determining the salinity characteristics of Mississippi Sound and adjacent waters.

Butler (1949) was impressed with the effect of the Pearl River and submitted some interesting data. He said:

> The question then naturally arises,—why should this area in Mississippi Sound suddenly, i.e., since the flood of 1945, become either unproductive or have extensive mortalities? . . . The Bonnet Carré Spillway has not been operated during the four years, if we except a few days leakage

in the latter part of February, 1949. . . . If fresh water from only the Pearl River is the cause, we must assume that either mass mortalities have occasionally occurred in the past or that some recent changes in this drainage basin have taken place.

Butler gave data showing that from 1943 to 1947 salinities that were too low for oysters occurred in the first part of the year and were correlated with the discharge rate of the Pearl River for all of the six years for which he had data. His graphs are quite striking. He showed that from February to May, 1949, the salinities in western Mississippi Sound were below 1.0 part per thousand. Butler said:

> These data demonstrate that in the years 1946, 1947 and 1949 when mass mortalities occurred in the west end of Mississippi Sound, there were greatly increased rates of fresh water discharge from the Pearl River Basin. . . .
>
> On the basis of the records for the past ten years, it is reasonable to expect that whenever the mean daily discharge rate from the Pearl River Basin exceeds 20,000 second-feet for the period January through June, there will be significant oyster mortalities in the west end of Mississippi Sound. . . .

The discharge data on the Pearl River are given in Table IX.

It is obvious that the Pearl River and the Bonnet Carré Spillway together lower salinities in Mississippi Sound and, doubtless, if either operated alone there would be fewer fatal salinities in the area. However, some mortalities are caused by the Pearl River alone, according to Viosca (1938) and Butler *(op. cit.)*. Unfortunately, high water periods in the Mississippi and Pearl River will probably coincide more often than not.

Because of his observations on low salinity in western Mississippi Sound, and the strong chance of future low salinities there, Butler recommended that no rehabilitation work in the area be attempted. He said natural seed should be harvested and moved away in the years in which they were prolific. In effect, Butler recommended that western Mississippi Sound oyster beds be abandoned to the low salinities which would hold there during many if not the majority of years. This is a marginal or submarginal territory for oysters and Butler's recommendation is obviously a wise one.

GENERAL DISCUSSION AND CONCLUSIONS CONCERNING THE BONNET CARRÉ SPILLWAY

The Bonnet Carré Spillway lies in an old crevasse area and the openings of the spillway have the effect of a major crevasse on the marine life of Mississippi Sound and adjacent waters.

In Lake Pontchartrain the motile marine organisms are chased out into Lake Borgne and beyond. Certain non-motile forms are killed. A small area of the bottom of Lake Pontchartrain is covered with a mud deposit. No deposits of mud or silt affects any beds or bottoms of Mississippi Sound and adjacent waters following spillway openings. Most mud and silt is deposited in the floodway proper and in Lake Pontchartrain.

In years of heavy spillway discharge, about 100 per cent of the oysters in Mississippi Sound west of Bay St. Louis are killed. Except for one major seed bed, Grand Bank, in the western Sound, the oysters in this region are of little consequence. Butler (1949) has pointed out that oysters in this region are subject to damage frequently from the Pearl River and that the bottoms should not be utilized for private or State cultivation. East of that line to Pass Christian mortality is about 50 per cent. In the northern

TABLE X

Pearl River Discharge
Sum of Measurements in Thousand Second-Feet at Bush and Bogalusa, La.
Above 600,000 is injurious to oysters in Mississippi Sound

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly Total
1939	305	652	844	511	211	454	155	110	70	83	61	63	3,539
1940	127	545	329	556	507	124	943	291	94	78	102	608	4,304
1941	446	273	454	387	158	100	184	138	77	68	78	254	2,617
1942	318	249	522	275	222	118	127	185	139	89	96	244	2,584
1943	487	314	939	715	149	94	96	74	140	67	120	134	3,329
1944	317	384	818	1,178	788	187	99	136	98	82	124	202	4,413
1945	410	633	1,024	678	301	298	235	164	91	131	102	244	4,311
1946	688	960	904	380	531	462	409	289	135	95	225	268	5,346
1947	1,145	539	749	1,183	475	220	140	115	153	92	203	483	5,497
1948	279	743	1,329	485	165	104	108	116	131	92	464	1,238	5,254
1949	1,059	1,160	841	1,089	571	342	388	271	172	137	122	140	6,292
1950	1,074	987	1,063	366	647	203	-----	-----	-----	-----	-----	-----	-----

Louisiana Marsh, the mortality ranges upward to 100 per cent but it is considerably less southward.

On the basis of discharge records, it appears that somewhere between 12,500,000 and 24,500,000 acre-feet of water there lies a critical point where flood waters coming through the spillway cause extensive damage to the Mississippi oyster beds between Bay St. Louis and Cat Island and the Louisiana beds in the Marsh.

The effect of the spillway waters is influenced by several other factors. If the discharge is fast, and remains on the beds a short time, mortality will not result. If the spillway waters come early in the season, when condition of the oysters is good and the temperatures are low, mortality will be less than in later months. Mortality from low salinities is produced by a combination of fresh water from the spillway and the Pearl River. If the Pearl River discharge is low, previous to spillway openings, oyster mortality will be at a minimum.

Spillway discharges always kill out oyster pests and predators and put thousands of tons of nutrient salts into the area. In 1950 this amount was estimated at over 50,000 tons. Because of the nutrient salts brought in by the river water a greater abundance of shrimp and other marine life may normally be expected following the return of normal salinities.

Concerning the influence of fresh water, Owen and Walters (1950) stated:

> It is essential for the maintenance of a successful oyster population that there be a source of nutrient-bearing fresh water. During the past few years Pearl River has had above normal drainage into the Sound. This undoubtedly has created an adverse environment for oysters on the northern shore of the Sound and frequently for those reefs immediately opposite the mouth on the southern shore (Butler 1949). In the opinion of the authors, however, this is far outweighed by the benefits to those reefs in the southern region of the 'Louisiana Marsh' and to those of eastern Mississippi Sound.

This statement holds true of any fresh water influx and is also applicable to the spillway. In every year the effect of the spillway is partly beneficial. In two out of three openings the effect has been all good. In one year the effect was partly destructive to oysters while benefiting those farther out. In the long run, it is quite probable that the total beneficial aspect of the spillway to the marine life of the affected area outweighs the oyster mortality caused in some years.

McConnell (1950) set forth some of the general benefits of fresh water and specific benefits of the Bonnet Carré Spillway. He said:

> The natural oyster reefs of Louisiana are very sharply restricted in location to the accessibility of available fresh water from the rivers or bayous. This production from the natural reefs today is derived entirely from the tributary waters. . . . Historically, these natural reef areas have had their periods of abundance and scarcity of oysters that have followed the pattern of the tributary drainage. . . .
>
> . . . There are no self-sustaining natural oyster communities in the high saline areas of the southern extremity of the marsh. Large temporary productive reefs are formed, exploited, and finally depleted in this area beyond the controlling factors of Pearl River. In 1899 Dr. Moore, of the then U. S. Bureau of Fisheries, reported that the natural reefs between Martin and Sam Holmes Islands, which were formerly productive, were completely depleted. In 1947 these identical reefs supported a most prolific population of market-sized oysters. The salinities of this area were reduced as a result of the opening of the Bonnet Carré Spillway during the early summer of 1945. In 1947 and 1948 man completely exploited these reefs to such an extent that it was exceedingly difficult to catch a single oyster. The area has been barren until this summer,

at which time a moderate strike has caught on the old shells. The reason for this latest natural rehabilitation lies in the reduced salinities caused by the 1950 opening of the Bonnet Carré Spillway.

Our natural reefs are so located that the periodic fluctuations of our tributary discharges are not felt on our natural reef industry as a whole. In the years of flood, the proper mixture of fresh and salt water produces conditions for natural rehabilitation of our normally high salinity reefs, which balance the mortalities of the low salinity reefs near the fresh water outlets. . . .

Viosca's (1928) discussion is the broadest presentation to date on the effect of Mississippi River floods upon the fisheries, aquatic life and wildlife. He treats of effects both in fresh and salt water and pointed out that in relation to salt water areas "the floods on the whole are decidely beneficial". He listed specifically benefits to oysters, fish, shrimp and the blue crab.

The Bonnet Carré Spillway was constructed specifically for flood control. It can also be viewed as a problem in biological engineering. The encroachment of salt water as a result of the levee system and its harmful effects on oysters has been a subject commented on many times. The first is in the Second Biennial Report of the Oyster Commission, State of Louisiana, (Feb. 1904–Feb. 1906). There are several subsequent comments in these reports which it is not necessary to quote. The latest comment is that of McConnell *(op. cit.)*. Even in Mississippi Sound the water sometimes becomes too salty for maximum oyster production. This has resulted in requests to the Corps of Engineers that the spillway be opened for the benefit of the oyster beds. Controlled openings for this purpose would be beneficial and feasible from a biological standpoint. This would cause some silting of the floodway unless the water were kept in a narrow channel. Whether or not such a project should be undertaken depends on the conflict between biological and flood control needs. If the cost of these controlled openings is not too much, and the resultant silting does not seriously reduce the carrying capacity of the floodway, the controlled openings should be carried out. In this case, attempts to measure the improvement of oyster beds on a value basis, as shown by increased production, should be made in cooperation with the proper State agencies. This would involve analysis of production figures and some examination of the beds before and after openings.

All vast engineering projects involving large land or water areas change the environment and the biological potential or productivity. In some cases it may be increased. Value assays of such projects should include biological considerations. Certainly any attempt to enhance the biological productivity of an area through an engineering project, such as manipulating the Bonnet Carré Spillway to help the oyster industry in dry years, is all in the public interest.

RELATION OF THE BOHEMIA SPILLWAY AND BAPTISTE COLLETTE GAP TO OYSTERS OF NEARBY WATERS

This area was studied during the same high water period that brought on the 1950 opening of the Bonnet Carré Spillway. It lies farther down the river on the east bank. Since the situation was somewhat different it is presented for the sake of comparison with Mississippi Sound and also to complete the report of the author's study of the flood water-oyster problem along the lower Mississippi in 1950.

Baptiste Collette Gap appeared as a break through the levee on the east side of the river just opposite the town of Venice in the early 1900's. By 1908 it was 300 feet

wide and 18 feet deep (Third Biennial Report, Oyster Commission of Louisiana, 1908). It was reported to be burying oysters in several feet of sand in the "Salt Works" and was said to have been ruining oyster beds for the previous 5 years.

This Gap is now the fartherest upstream permanent distributary of the river on the east bank. Figure 7 is a map of the region. Practically no oysters are produced south of Baptiste Collette Gap, although there are a few beds between the Passes at the river mouth.

About 25 miles north of the Gap lies the Pointe-a-la-Hache Relief Outlet, more commonly known as the "Bohemia Spillway." This is essentially a gap cut in the levee by the New Orleans Levee Board between 1922 and 1924 between Bohemia and Bayou LaMoque, a distance of about 10 miles. During high water the river flows through this cut into American Bay, Long Bay and California Bay. Reports of destruction of oysters in this region in 1927 and 1944 by the Department of Wild Life and Fisheries have already been mentioned. In the Eleventh Biennial Report of the Department of Conservation (1932–1933) it was stated that during the spring and early summer of 1933 water from the Bohemia Outlet caused the loss of 1,000,000 barrels of oysters. The area was said to have extended from Half Moon and Petit Pass Islands in St. Bernard Parish to Bayou La Mere, Oak River, American Bay, California Bay and La Fortune in Plaquemines Parish. Due to the physiography of the region, it is virtually impossible for water going through the Bohemia Outlet to affect oysters at Half Moon and Petit Pass in Mississippi Sound. Most likely the damage was caused by the Pearl River. In 1945 all destruction was attributed to the Bonnet Carré Spillway, and the Relief Outlet was not mentioned, although discharge was greater in 1945 than it was in 1944. It should be remembered, however, if the oysters were killed out in that area in 1944 there would have been few left to damage in 1945. Discharge data on the Relief Outlet and Baptiste Collette Gap were presented in a table (Gunter, 1950).

Considerable numbers of oysters are still produced in American Bay, California Bay and vicinity. The area is shallow and difficult to traverse. Examinations of the oysters were made on 14 February, 16 March, 14 April and 26 July, 1950. Water samples were taken more often. The stations are shown on the map, figure 7.

Table XI gives the salinities taken at the various stations. Weekly salinity samples were taken. This table shows that low salinities were present over most of the area from 14 February to 24 March. American Bay and Quarantine Bay had the lowest salinities, as was to be expected, since they lie closest to the outlet. Low salinity water was present over these beds for about six weeks. The fresh water did not reach California Point until 10 days later and was present a month. At Raccoon Pass the fresh

TABLE XI

Salinities in parts per thousand at oyster stations in the area affected by the Bohemia Spillway

	Feb. 14	Feb. 24	Mar. 10	Mar. 16	Mar. 24	Mar. 31	Apr. 7	Apr. 14	July 26
Quarantine Bay	.08	1.07	1.74	1.24	.54	18.98	14.29	14.29	19.88
California Point	6.17	.93	.16	1.20	1.08	15.19	10.50	11.76	25.75
American Bay	.....	.13	.12	.06	.17	8.69	8.33	9.42	22.59
Black Bay	5.62	.53	5.90	.80	.17	15.28	10.50	11.76	25.75
Telegraph Point	....	.34	4.00	2.47	1.06	11.94	12.84	11.22	25.75
Raccoon Pass	19.88	6.12	1.51	1.20	5.62	18.44	13.75	15.37	27.10
Mouth of Fort Bayou	....	7.16	3.03	4.27	14.11	20.61	14.47	15.55	....
Grand Bay	....	1.56	4.96	6.35	2.58	21.33	9.60	10.32	17.63

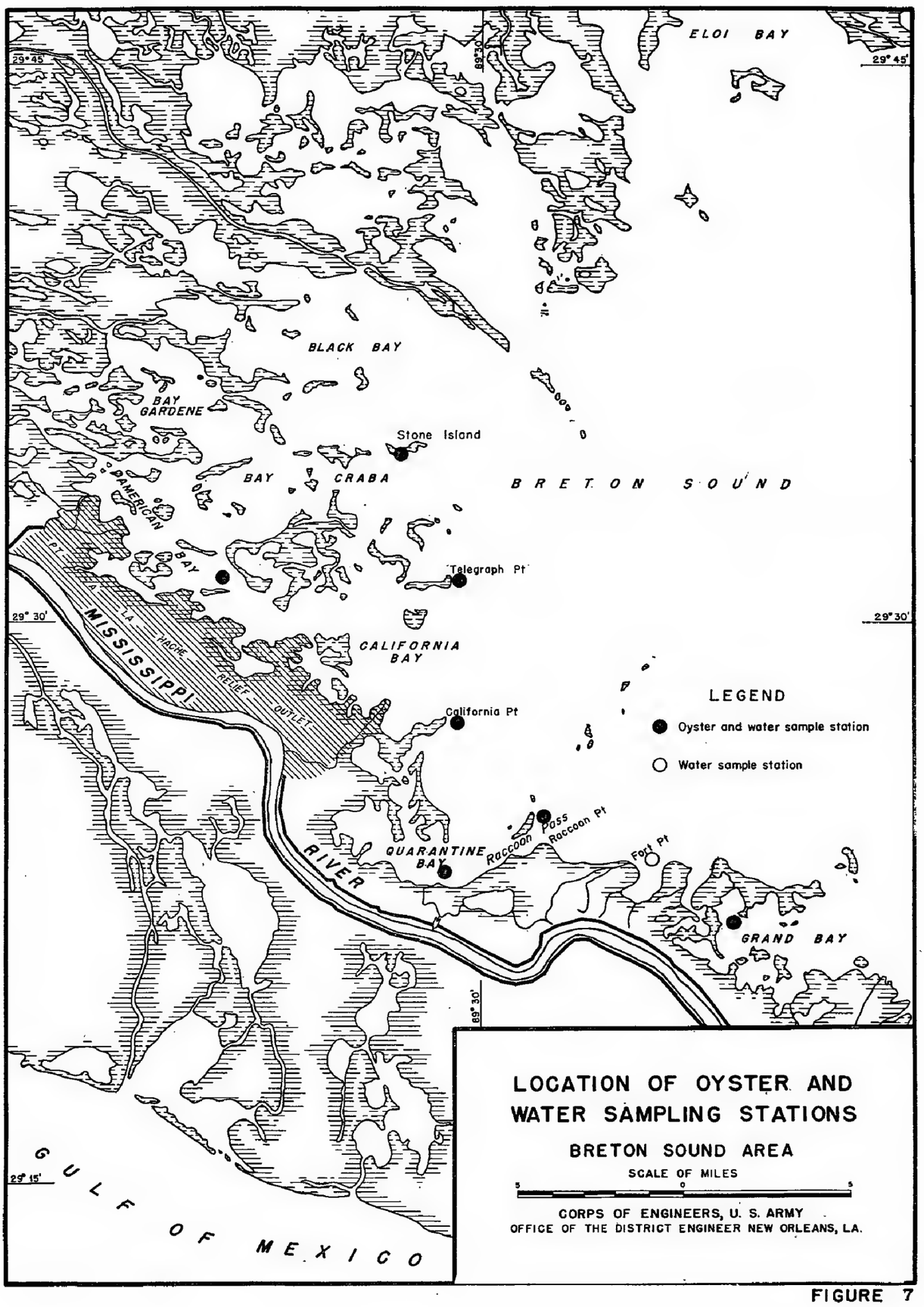
ELOI BAY
29° 45'
89° 30'
BLACK BAY
BAY GARDENE
Stone Island
BAY CRABA
BRETON SOUND
AMERICAN BAY
Telegraph Pt
29° 30'
MISSISSIPPI
LA MACHE
RELIEF
OUTLET
CALIFORNIA BAY
California Pt
LEGEND
Oyster and water sample station
Water sample station
Raccoon Pass
Raccoon Pt
Fort Pt
QUARANTINE BAY
RIVER
GRAND BAY
89° 30'
GULF OF MEXICO
29° 15'
LOCATION OF OYSTER AND WATER SAMPLING STATIONS
BRETON SOUND AREA
SCALE OF MILES
5 0 5
CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER NEW ORLEANS, LA.

FIGURE 7

water was first in evidence about a month later and remained for about two weeks. At Grand Bay, Telegraph Point and Black Bay the salinities fluctuated and the reefs were not subjected to low salinities for any extended length of time. Fort Bayou was a hydrographic station.

Grand Bay was found to be a shallow body of water around two feet deep. The bottom was soft black mud. It is very poor for oysters. In spite of this fact, it is used as a bedding or growing ground. Every examination showed that the oysters were sinking in the mud and dying. This station was not visited on 14 February because the tide was almost two feet below normal and Grand Bay was almost dry. On 24 February it was found that condition of oysters was poor to fair. There were no signs of sexual development. The oysters were very sharp-edged. There were a few barnacles and worms present and a good many boring clams but perforations were few. The oysters showed a thin layer of silt. There was no abnormal mortality except that caused by soft mud. By 14 April these oysters had fattened and ripened sexually. Mortality was 5 in 255 oysters or 2 per cent. Boxes sunk in the mud were not counted. The July examination showed these oysters to be ripe and in good condition, except that they were sinking in the mud. There were 5 spat on 10 oysters and 15 dead out of 160 counted, or 9.4 per cent.

Examination of Table XI shows that Grand Bay had low salinities while stations to the north were salty. The indications are that this location was affected by water from Baptiste Collette Gap while the others were affected only by waters from the Bohemia Spillway.

The station at Raccoon Pass was a natural reef containing a good many market oysters. Boring clams and a few barnacles were present. The oysters were salty and fat. The general condition was good on 14 February. On 16 March the oysters were much fatter and several of them were milky. Mortality was less than 2 per cent. On 14 April the oysters were in excellent condition and many were ripe. A few spat were seen. Two recently dead oysters out of 158 were seen. On 21 July the oysters were ripe and in good shape. They were growing and many were covered with an encrusting sponge. Two spat on 10 shells were seen. Fifteen dead oysters found among 244 counted, a mortality of 6.1 per cent.

At California Point market boats were fishing oysters on 14 February. The oysters were in fair shape and had a few small barnacles and boring clams on them. They tasted fresh and had no crystalline styles. The water was muddy like the river. On 16 March the water was still muddy. The oysters had fattened and were becoming milky. Mortality was less than 2 per cent. On 14 April the oysters tasted salty. Their condition was fair to good and they were mature or maturing sexually. Six dead oysters among 228, a mortality of 2.6 per cent, were seen. On 24 July most oysters had spawned out. Condition had regressed and many were poor. There were 5 spat on 10 shells. Mortality was 21 in 287 oysters or 7.3 per cent.

The beds at Telegraph Point, Black Bay and American Bay were all seed beds and can be described together. They were small, mostly ill-shaped and sharp-edged. Mussels, barnacles and much boring clam were present. Only Black Bay was visited on 14 February because of low tide. The oysters were poor. On 16 March the oysters were fat and some were milky. The water was a muddy brown color over the beds. Condition was about medium or fair on all beds and all oysters tasted fresh. Mortality was 14.3 per cent among 105 oysters. On 14 April condition ranged from fair to good. Most

oysters were ripe. The mortality in American Bay was 27.7 per cent in 206 oysters counted. At the other two stations it was 3.2 per cent in 500 oysters. On 26 July most oysters were spawned out. Condition was poor to fair. A few barnacles and mussels and considerable encrusting yellow sponge were present. At American Bay and Black Bay the mortality was 13.7 per cent in 630 oysters. At Telegraph Point the mortality was 2.6 per cent among 308 oysters counted. There were 53 spat on 30 oysters.

The reef visited in Quarantine Bay was a natural towhead with oysters of mixed sizes. On 14 February barnacles and mussels were present but no clams were seen. Condition ranged from poor to good. The oysters were fresh, and no crystalline styles were present. Some oysters were dying and some gapers were seen. The remaining oysters had all fattened by 16 March. Mortality was 24.1 per cent. On 14 April the oysters were salty and in good condition. They were ripening sexually. Mortality was 23 in 240 oysters or 9.6 per cent. On 26 July much encrusting sponge and several baby stone crabs were present. Condition was poor to fair and many oysters were ripe. There were 12 spat on 10 shells. Mortality was 8.5 per cent of 118 oysters.

Boring sponges and boring clams and some barnacles were killed out in American, Quarantine and California Bays. However, they were not harmed at Raccoon Pass and Telegraph Point. At the former location many of the clams were ripe on 14 April and doubtless the whole area was soon reinfested.

Summary of Observations

The general condition for oysters was much poorer in this section than in the Louisiana Marsh and eastern part of Mississippi Sound. The area is shallow and muddy. During the first surveys all oysters showed a small, but plainly visible scum of silt. No conchs were seen at any time. There was considerable sign of previous heavy infestation of oysters by boring sponge and boring clams. These were killed out in Quarantine Bay, California Point and American Bay. They were not killed at Raccoon Pass, Telegraph Point and Grand Bay.

Observations confirmed those in Mississippi Sound concerning the fattening and ripening of oysters in the face of falling salinities and falling temperatures.

An examination of Table XI shows that fluctuations in salinity occurred more rapidly in this area than in Mississippi Sound and the Marsh. In American Bay and Quarantine Bay the mortality from fresh water seemed to be approximately 22 per cent. This is higher than any found in Mississippi Sound and the Louisiana Marsh. In spite of the 20 to 25 per cent mortality on some inshore beds, oysters on the lower river were benefited rather than harmed by the flood waters of 1950. Certain injurious organisms were killed out and large quantities of nutrient salts were brought into the waters.

It appears that, since the oysters of this region lie closer to the sources of fresh water, they are subject to more violent fluctuations of salinity there and are in a more precarious situation than those in the Sound. There is no lake to act as a salinity buffer or settling basin for silt. Therefore, they are also subject to siltation. However, there were no signs that silting was extensive enough to do damage in this region in 1950. Mortalities from low salinity can be expected here more often than in Mississippi Sound and the Louisiana Marsh.

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APPENDIX I

DESCRIPTION OF OYSTER BEDS IN MISSISSIPPI SOUND AND THE LOUISIANA MARSH

Condition, fatness, mortality, and stage of gonad development varied during the period of the examinations. These factors have been described in the body of the report in enough detail and they are not considered here. By and large the reefs are described as they were found to be in the first two examinations.

a. Inshore Reefs of the State of Mississippi (Mississippi Sound)

Pass Christian Tonging Ground

This reef is about 2½ miles long. Most oysters were under market size. They were very abundant, rounded, and densely clumped. A few market oysters were present on the edge of the reef. There was much new shell. Considerable mussels were present and many barnacles were present. A few mudworms were present. There were no other commensals. This was a hard shell reef containing several thousand barrels of oysters.

Henderson Point (Hornet Reef)

Oysters were prolific, clumped and mostly of good, round shape. They were very sharp-edged and were mostly around 2 inches long. They had the whitish appearance of low salinity oysters. There

were many small barnacles and some mussels present. There were many mudworm blisters present. Older oysters showed former heavy infestation by boring sponges and boring clams. This was a hard reef, thickly covered with seed and oysters just under market size.

Square Handkerchief Reef

This reef is about a mile square. It is soft in spots and there is considerable shell. Shell was planted there by the Mississippi Seafoods Commission before the 1947 hurricane. There were some market oysters on that part of the reef. Forty thousand barrels of seed were also planted on this reef in May, 1949. They showed little growth. However, all oysters were sharp-edged at the time of examination. The oysters were not round, but oblong and were somewhat clumped. Mudworm blisters were abundant and large barnacles and mussels were abundant. Perforations by boring clams were numerous.

Middle Channel Reef

This reef contained thick, prolific seed or sub-market size oysters. They were sharp-edged and clumped. Both mussels and barnacles were thick in spots and some were large. There were few boring clams but mudworm infestation was heavy. A few oysters were market size. This was a solid reef with no mud on it.

b. Louisiana Seed Reefs in Mississippi Sound

Grand Bank

This is a large, hard, shell reef thickly covered with round, clumped, seed oysters. They were white, low salinity oysters with sharp edges, showing recent growth. Commensals were few. There were a few barnacles and mussels and some perforations from boring clams.

Half Moon

This is a scattered reef, muddy in spots and with considerable dead shell. The oysters were in small patches. They were small and not large enough to be good seed. They were white, clumped and sharp-edged. Barnacles and mussels were thick. Boring clams were not seen. There were not many oysters on the reef. It is of little value.

c. Offshore Reefs in Mississippi Sound

Telegraph Key

This is a hard, shell reef. A few oysters were market size, but most were small ranging down to three-fourths of an inch in size. They were clumped and sharp-edged. Mussels and barnacles were thick in spots. Boring sponge was present in considerable abundance. Mudworms and boring clams were present. At the time of the first examination the oysters were white and sharp-edged. Six months later they were green and showed no recent growth. This is a Mississippi reef.

Pelican Key

This is a hard reef. There was little small stuff. The oysters were round with scalloped shells. Oysters were not prolific but many were market size. There was little recent growth. Mussels and barnacles were few. Bryozoa were present. The oysters were strong and hard to open. In February many *Thais* were brought up with each load. The reef showed all signs of being exposed to high salinity. It is a Mississippi reef.

Isle au Pitre

This reef is one of the few Louisiana reefs lying in Mississippi Sound which produce market oysters. Oysters were scattered in spots and mixed with considerable shell. There was a little recent growth of shell. They ranged from small seed to market size. They were green and the larger ones had scalloped shells. Mussels were not seen. There were a few barnacles. Boring clam perforations were common. One ripe oyster was seen in February and many conchs were present at that time.

d. The Louisiana Marsh Reefs

The "Marsh" region can be characterized as a whole. By and large it was a region of market oysters. They were predominant on most reefs and a few hundred oyster boats were working over the whole area. The shape of oysters was variable but mostly good. The reefs were rather heavily fished and there was considerable mixture of old shell on some of them. Sharp, new shell

was present in most localities but it was not as prolific as on the Sound reefs. The oysters were green or dark and did not have the color of low salinity oysters.

Mudworms varied from few to thick in abundance. Few barnacles and mussels were present. Sponge varied from none to thick from the northern part of the Marsh southward. Boring clams were extremely abundant except in the northern part of the marsh. Conchs were present on the lower more saline reefs in the lower Marsh. The oysters were fatter than in the Sound and a few were ripe or nearly so in February.

e. Description of Reefs and Locations Visited Only Once in Mississippi Sound and the Louisiana Marsh

Cat Island is a reef consisting largely of dead shell in 25 feet of water. A few large oysters with thick heavy shells were found. They were in excellent condition. There was practically no shell growth. Many boring clams were present in the shells of live oysters.

At Waveland and at the mouth of Heron Bay, oysters were buried under one foot of mud. According to Captain Filopich, oysters were planted at Waveland by the State in May, 1947, but they were covered by mud by the hurricane in September.

Scattered oysters, but no reef of any consequence, were found at Petit Pass. The oysters were white, as is characteristic of those living in low salinities, round, clumped and sharp-edged, showing recent shell growth. They were fat.

Three Mile Reef, near the Louisiana Marsh, is dead shell, which was planted under the direction of the Louisiana Department of Wild Life and Fisheries. A very few small oysters were present. Old scars showed that oysters seemed to set a little on these shells and die. This confirms the previous observation of Butler (1949).

APPENDIX II

RESULTS OF WATER ANALYSES 1950 BONNET CARRÉ SPILLWAY OPERATION

Spillway Weir
(At Bay No. 175)

Date	Chlorine Cl- p.p.m.	Dissolved Solids p.p.m.	Suspended Solids p.p.m.	Temperature Degrees C.	pH
13 Feb.	10	172	630	11.7	----
16 Feb.	12	236	1,291	10.0	7.80
20 Feb.	10	176	1,437	9.7	7.78
23 Feb.	11	138	1,470	9.4	7.63
27 Feb.	11	222	1,396	----	7.85
2 Mar.	9	208	2,126	10.3	7.76
6 Mar.	8	158	1,439	8.9	7.86
9 Mar.	9	228	1,321	8.9	7.94
13 Mar.	9	230	1,081	9.7	8.02
16 Mar.	9	182	718	9.4	8.15

Spillway Weir
(At Bay No. 65)

13 Feb.	10	208	1,124	----	----
16 Feb.	9	172	1,236	----	7.79
20 Feb.	10	178	951	----	7.86
23 Feb.	11	146	1,076	----	7.58
27 Feb.	11	198	1,041	----	8.01
2 Mar.	9	188	1,284	----	7.86
6 Mar.	9	174	1,174	----	7.91
9 Mar.	9	182	1,010	----	7.78
13 Mar.	9	188	1,134	----	7.78
16 Mar.	8	184	374	----	8.23

Spillway Weir
(At Bay No. 263)

Date	Chlorine Cl- p.p.m.	Dissolved Solids p.p.m.	Suspended Solids p.p.m.	Temperature Degrees C.	pH
13 Feb.	10	194	722	-----	-----
16 Feb.	11	206	965	-----	-----
20 Feb.	10	172	1,160	-----	7.92
23 Feb.	11	142	1,114	-----	7.60
27 Feb.	11	232	953	-----	7.87
2 Mar.	9	248	1,062	-----	7.95
6 Mar.	10	188	1,087	-----	7.82
9 Mar.	13	192	927	-----	7.71
13 Mar.	10	236	532	-----	8.06
16 Mar.	10	206	540	-----	8.03

Spillway Highway Bridge
(At Station 15+00)

14 Feb.	10	132	368	-----
16 Feb.	10	202	400	-----
20 Feb.	14	192	437	7.54
23 Feb.	24	172	451	7.65
27 Feb.	11	186	466	7.83
2 Mar.	10	172	536	7.85
6 Mar.	8	162	540	7.86
9 Mar.	11	224	500	7.95
13 Mar.	9	180	484	8.01
16 Mar.	10	204	435	7.99

Spillway Highway Bridge
(At Station 30+00)

14 Feb.	10	160	478	-----
16 Feb.	9	102	549	7.80
20 Feb.	13	172	765	7.81
23 Feb.	11	234	844	7.69
27 Feb.	12	238	980	7.90
2 Mar.	10	170	1,499	7.88
6 Mar.	9	162	1,091	7.86
9 Mar.	9	190	941	7.96
13 Mar.	9	190	946	8.00
16 Mar.	9	418	759	8.48

Spillway Highway Bridge
(At Station 45+00)

14 Feb.	10	150	526	-----
16 Feb.	10	138	695	-----
20 Feb.	13	178	933	7.81
23 Feb.	11	178	868	7.67
27 Feb.	11	244	935	7.92
2 Mar.	9	202	1,081	7.80
6 Mar.	9	150	904	7.90
9 Mar.	12	180	1,107	8.01
13 Mar.	9	180	783	7.94
16 Mar.	14	320	857	8.01

Spillway I.C.R.R. Bridge
(At Station 26+00)

14 Feb.	11	150	337	-----
16 Feb.	10	236	383	7.73
20 Feb.	14	196	377	7.78
23 Feb.	11	182	448	7.60
27 Feb.	11	240	427	7.80
2 Mar.	25	214	432	7.81
6 Mar.	8	204	437	7.77
9 Mar.	9	172	475	7.94
13 Mar.	10	188	324	7.88
16 Mar.	10	194	348	7.88

SPILLWAY I.C.R.R. BRIDGE
(At Station 52+00)

Date	Chlorine Cl- p.p.m.	Dissolved Solids p.p.m.	Suspended Solids p.p.m.	pH
14 Feb.	11	294	324	-----
16 Feb.	11	208	292	7.91
20 Feb.	14	198	386	7.73
23 Feb.	11	176	352	7.62
27 Feb.	11	310	372	7.80
2 Mar.	16	200	390	7.77
6 Mar.	9	160	372	7.81
9 Mar.	9	160	467	7.78
13 Mar.	11	164	289	7.92
16 Mar.	10	230	339	8.15

SPILLWAY I.C.R.R. BRIDGE
(At Station 87+00)

14 Feb.	10	106	374	-----
16 Feb.	10	194	402	7.69
20 Feb.	13	186	459	7.64
23 Feb.	11	168	352	7.58
27 Feb.	11	316	364	7.84
2 Mar.	11	166	411	7.70
6 Mar.	13	140	381	7.80
9 Mar.	10	174	409	7.88
13 Mar.	15	168	334	7.92
16 Mar.	10	338	300	8.02

FRENIER

13 Feb.	39	216	468	7.78
17 Feb.	35	206	194	8.02
24 Feb.	22	192	131	7.87
3 Mar.	23	198	525	7.78
10 Mar.	24	190	407	8.01
17 Mar.	56	212	251	7.92
21 Mar.	34	192	464	7.89
28 Mar.	34	202	934	7.56
3 Apr.	42	70	651	8.09
10 Apr.	27	40	578	7.60
17 Apr.	35	276	51	-----

PASS MANCHAC

10 Feb.	62	-----	-----	-----
13 Feb.	550	870	88	-----
28 Feb.	48	152	49	7.08
6 Mar.	50	200	52	7.24
13 Mar.	55	188	35	-----
20 Mar.	32	132	11	7.39
27 Mar.	29	166	106	7.28
2 Apr.	25	186	87	7.64
10 Apr.	33	138	21	7.28
17 Apr.	26	46	30	7.92

WEST END

10 Feb.	1,000	2,178	34	-----
18 Feb.	900	1,810	36	7.49
23 Feb.	550	1,240	64	7.82
4 Mar.	100	690	135	7.30
10 Mar.	47	222	202	7.98
17 Mar.	75	292	178	8.00
24 Mar.	40	262	69	7.98
31 Mar.	31	195	83	7.78
7 Apr.	70	216	71	7.73
14 Apr.	30	224	144	7.76
21 Apr.	39	240	81	7.72

Little Woods

Date	Chlorine Cl- p.p.m.	Dissolved Solids p.p.m.	Suspended Solids p.p.m.	pH
24 Feb.	850	-----	-----	-----
3 Mar.	400	-----	-----	-----
10 Mar.	150	-----	-----	-----
12 Mar.	110	390	71	8.14
17 Mar.	160	488	128	7.78
21 Mar.	100	340	105	7.98
28 Mar.	85	426	130	7.98
3 Apr.	33	112	67	8.03
10 Apr.	31	216	48	8.17
16 Apr.	160	276	92	7.72

Mandeville

10 Feb.	1,000	1,630	137	-----
17 Feb.	850	1,940	69	7.31
24 Feb.	-----	-----	-----	-----
3 Mar.	485	984	94	7.22
10 Mar.	310	612	262	7.20
17 Mar.	148	550	61	7.48
21 Mar.	220	518	28	7.38
28 Mar.	130	414	342	7.58
4 Apr.	105	312	116	7.44
11 Apr.	185	440	77	7.49
18 Apr.	50	138	37	8.10

North Shore

10 Feb.	1,120	1,720	65	-----
17 Feb.	850	1,790	23	7.28
24 Feb.	800	1,750	11	7.20
3 Mar.	475	968	20	7.46
10 Mar.	345	732	21	7.15
17 Mar.	150	390	28	7.78
21 Mar.	300	704	22	7.69
28 Mar.	86	279	155	7.56
4 Apr.	60	220	54	7.78
11 Apr.	80	304	75	8.09
18 Apr.	72	274	32	8.21

Chef Menteur

11 Feb.	1,470	2,560	51	-----
17 Feb.	950	2,100	39	7.58
3 Mar.	235	508	84	7.86
10 Mar.	17	-----	223	8.01
17 Mar.	17	-----	152	8.06
21 Mar.	34	-----	99	8.10
28 Mar.	57	-----	121	7.98
4 Apr.	80	-----	178	-----
11 Apr.	45	-----	103	-----
18 Apr.	77	212	72	-----

Rigolets

11 Feb.	660	1,030	51	-----
17 Feb.	1,100	2,560	6	7.52
3 Mar.	47	-----	82	7.80
10 Mar.	139	-----	145	7.78
17 Mar.	14	-----	109	7.88
21 Mar.	107	-----	102	8.16
28 Mar.	43	-----	210	7.63
4 Apr.	39	92	73	7.52
11 Apr.	35	112	85	7.73
18 Apr.	43	116	43	7.78
4 May	50	158	94	8.31
18 May	50	176	66	7.62
1 June	90	242	90	7.28
15 June	220	590	58	7.94
29 June	240	658	95	7.96

Pearl River

Date	Chlorine Cl- p.p.m.	Dissolved Solids p.p.m.	Suspended Solids p.p.m.	pH
24 Feb.	5	70	45	7.12
3 Mar.	4	60	30	7.02
10 Mar.	5	46	29	6.98
17 Mar.	18	104	28	7.42
23 Mar.	7	142	14	7.86
29 Mar.	7	140	14	6.66
6 Apr.	6	80	11	6.92
13 Apr.	8	44	15	7.30
20 Apr.	10	74	25	7.28

Clermont Harbor

11 Feb.	1,290	2,340	16	-----
17 Feb.	1,250	2,900	10	7.43
24 Feb.	350	930	256	7.08
3 Mar.	195	448	119	7.08
10 Mar.	160	436	251	6.85
17 Mar.	85	246	122	7.47
23 Mar.	125	364	166	7.56
29 Mar.	400	828	1,148	7.25
6 Apr.	400	908	95	7.44
13 Apr.	290	654	17	7.45
20 Apr.	1,500	3,272	13	7.92
4 May	2,450	5,096	103	-----
18 May	900	1,980	16	-----
1 June	2,750	5,390	43	7.79
15 June	5,250	10,634	47	7.71
29 June	6,000	12,168	71	7.71

Bay St. Louis

11 Feb.	2,100	4,600	25	-----
17 Feb.	1,100	2,580	8	6.73
24 Feb.	500	1,120	40	7.08
3 Mar.	65	220	91	6.88
10 Mar.	115	264	58	6.75
17 Mar.	117	270	70	7.36
23 Mar.	75	316	227	7.58
29 Mar.	100	300	151	7.39
6 Apr.	1,320	2,794	19	7.78
13 Apr.	130	348	28	7.32
20 Apr.	3,350	6,302	4	7.78

Gulfport

11 Feb.	5,275	11,040	8	-----
17 Feb.	7,500	15,710	910	7.68
24 Feb.	3,950	8,090	17	7.50
3 Mar.	4,200	8,200	16	7.53
10 Mar.	3,200	6,676	7	7.57
17 Mar.	5,250	11,230	98	8.03
23 Mar.	800	1,774	31	7.50
29 Mar.	1,290	2,534	914	7.64
6 Apr.	4,800	9,376	59	7.64
13 Apr.	6,600	13,194	23	7.72
20 Apr.	10,750	28,220	25	7.56
4 May	6,000	12,114	96	-----
18 May	5,500	10,954	13	-----
1 June	9,125	21,328	19	7.97
15 June	9,500	19,292	27	7.60
29 June	12,500	25,124	50	8.23

Biloxi

Date	Chlorine Cl- p.p.m.	Dissolved Solids p.p.m.	Suspended Solids p.p.m.	pH
11 Feb.	7,650	16,180	1	----
17 Feb.	9,200	19,170	12	7.69
24 Feb.	4,750	9,590	6	7.43
3 Mar.	5,850	11,624	6	7.41
10 Mar.	5,500	11,496	11	7.67
17 Mar.	1,610	3,312	40	7.28
23 Mar.	7,850	17,778	66	7.62
29 Mar.	1,880	3,920	148	7.49
6 Apr.	4,000	8,040	19	7.63
13 Apr.	8,200	18,858	15	7.84
20 Apr.	11,500	21,190	51	7.83
4 May	7,500	16,778	26	----
18 May	4,500	9,546	31	----
1 June	9,750	22,796	22	7.76
15 June	10,250	19,588	55	7.59
29 June	11,750	23,506	33	7.97

Magnolia State Park

11 Feb.	5,350	54,170	20	----
17 Feb.	4,450	8,930	112	7.22
24 Feb.	6,100	12,220	44	7.46
3 Mar.	4,150	8,240	94	7.22
10 Mar.	2,950	6,184	19	7.39
17 Mar.	1,500	3,048	62	7.27
23 Mar.	1,920	3,892	235	7.37
29 Mar.	1,160	2,376	182	7.18
6 Apr.	2,500	4,892	5	7.36
13 Apr.	3,750	7,490	72	7.33
20 Apr.	7,500	15,528	19	7.38

Grand Bank

11 Feb.	3,200	5,300	55	----
23 Feb.	900	1,600	67	7.38
2 Mar.	475	1,140	106	7.38
9 Mar.	150	428	137	7.80
15 Mar.	50	240	140	8.01
23 Mar.	50	304	65	7.97
30 Mar.	93	252	105	7.65
6 Apr.	1,180	2,428	126	7.72
12 Apr.	1,520	3,122	41	7.60
24 July	11,500	22,122	18	----

Grand Island (Half Moon)

11 Feb.	2,000	3,000	111	----
23 Feb.	850	1,880	7	----
15 Mar.	50	270	151	8.18
30 Mar.	46	150	101	7.42
12 Apr.	320	776	95	7.52
24 July	9,000	18,354	13	----

Quarantine Bay (Post No. 88)

Date	Chlorine Cl- p.p.m.	Dissolved Solids p.p.m.	Suspended Solids p.p.m.	pH	Temperature Degrees C.
14 Feb.	27	640	476	----	----
24 Feb.	575	1,464	149	7.83	15.0
10 Mar.	950	2,040	195	7.98	14.8
16 Mar.	670	1,526	204	7.82	----
24 Mar.	280	658	144	7.91	20.5
31 Mar.	10,500	19,864	37	8.04	17.2
7 Apr.	7,900	16,588	25	7.78	16.7
14 Apr.	7,900	17,010	4	7.98	18.6
26 July	11,000	22,644	57	----	29.4

BLACK BAY
(Stone Island)

Date	Chlorine Cl- p.p.m.	Dissolved Solids p.p.m.	Suspended Solids p.p.m.	pH	Temperature Degrees C.
14 Feb.	3,100	5,840	129	-----	-----
24 Feb.	275	984	131	7.87	14.4
10 Mar.	3,250	6,634	106	7.75	14.4
16 Mar.	425	1,002	145	7.98	----
24 Mar.	80	1,018	114	7.92	20.0
31 Mar.	8,450	17,712	124	7.82	16.7
7 Apr.	5,800	12,766	33	7.88	16.1
14 Apr.	6,500	12,848	100	7.79	18.3
26 July	14,250	28,728	45	-----	29.4
CALIFORNIA POINT					
14 Feb.	3,400	6,530	102	-----	-----
24 Feb.	500	1,292	125	7.86	13.9
10 Mar.	70	338	323	7.96	12.8
16 Mar.	650	1,348	145	7.94	----
24 Mar.	580	1,266	78	8.01	19.2
31 Mar.	8,400	15,906	56	8.13	17.0
7 Apr.	5,800	11,572	18	7.92	15.8
14 Apr.	6,500	12,614	103	7.91	18.6
26 July	14,250	26,916	28	-----	29.1
AMERICAN BAY					
24 Feb.	55	350	146	-----	12.2
10 Mar.	50	292	217	8.10	12.2
16 Mar.	19	236	175	7.73	----
24 Mar.	80	308	110	7.92	18.3
31 Mar.	4,800	9,692	79	8.35	16.7
7 Apr.	4,600	9,092	26	7.88	15.8
14 Apr.	5,200	10,230	52	7.78	18.3
26 July	12,500	26,314	29	-----	28.6
TELEGRAPH POINT					
24 Feb.	170	590	147	-----	14.4
10 Mar.	2,200	4,548	141	7.82	13.9
16 Mar.	1,350	3,202	65	7.86	----
24 Mar.	570	1,232	84	8.01	19.4
31 Mar.	6,600	13,824	38	7.94	16.4
7 Apr.	7,100	14,962	42	7.87	15.6
14 Apr.	6,200	12,382	63	7.90	17.5
26 July	14,250	27,786	24	-----	29.4
RACCOON PASS					
14 Feb.	11,000	21,750	40	-----	-----
24 Feb.	3,375	7,216	17	7.88	13.9
10 Mar.	820	1,794	144	7.84	13.6
16 Mar.	650	1,348	145	7.94	----
24 Mar.	3,100	6,248	29	7.83	18.3
31 Mar.	10,200	23,490	100	8.00	16.7
7 Apr.	7,600	15,128	53	7.87	15.3
14 Apr.	8,500	17,544	35	7.93	20.5
26 July	15,000	30,420	49	-----	30.2
MOUTH OF FORT BAYOU					
24 Feb.	3,950	7,960	----	-----	15.0
10 Mar.	1,660	3,492	406	7.91	13.3
16 Mar.	2,350	4,814	61	7.87	----
24 Mar.	7,800	13,530	23	7.89	18.3
31 Mar.	11,400	23,130	21	8.02	16.7
7 Apr.	8,000	17,174	26	7.93	15.6
14 Apr.	8,600	17,850	110	7.94	18.3

Grand Bay

Date	Chlorine Cl- p.p.m.	Dissolved Solids p.p.m.	Suspended Solids p.p.m.	pH	Temperature Degrees C.
24 Feb.	850	1,880	7		13.9
10 Mar.	2,730	5,584	104	7.88	13.1
16 Mar.	3,500	7,086	123	7.82	
24 Mar.	1,410	2,840	69	7.79	18.3
31 Mar.	11,800	27,174	79	7.92	15.6
7 Apr.	5,300	11,124	44	7.82	13.9
14 Apr.	5,700	10,988	54	8.07	20.3
26 July	9,750	18,602	55		29.1
Pass Christian Tonging Reef (½ Mile Off Shore)					
10 Feb.	4,180	8,184	55		
15 Mar.	75	230	149	7.34	
13 Apr.	2,200	4,646	64	7.50	18.3
Pass Christian Tonging Reef (2 Miles Off Shore)					
10 Feb.	4,500	8,600	58		
15 Mar.	65	202	118	7.56	
13 Apr.	900	2,110	84	7.55	18.3
25 July	11,500	23,632	35		29.4
Henderson Point Channel					
12 Feb.	3,000	5,920	32		
15 Mar.	30	144	59	7.38	
13 Apr.	650	1,500	35	7.35	18.6
24 July	10,250	21,202	21		29.7
Square Handkerchief Reef					
12 Feb.	2,400	4,590	23		
15 Mar.	45	214	77	7.73	
13 Apr.	2,200	4,558	43	7.55	18.6
24 July	10,500	21,506	24		30.0
Middle Channel Reef					
10 Feb.	4,900	9,506	32		
15 Mar.	55	214	97	7.68	
13 Apr.	2,950	6,134	42	7.52	18.6
25 July	12,300	25,988	25		29.4
Telegraph Key					
11 Feb.	4,800	9,120	89		
15 Mar.	45	224	76	7.93	
13 Apr.	2,550	5,286	12	7.52	18.3
25 July	13,000	27,218	16		29.4
Cat Island Channel					
10 Feb.	9,200	18,068	28		
15 Mar.	70	206	109	7.77	
Pelican Key					
10 Feb.	8,100	15,926	94		
15 Mar.	80	268	110	7.81	
12 Apr.	6,200	13,500	10	8.15	19.4
25 July	13,500	26,212	14		29.4
Isle au Pitre					
12 Feb.	8,600	17,310	33		
14 Mar.	176	482	181	7.88	13.3
12 Apr.	6,600	14,510	19	8.05	19.4
25 July	14,500	27,840	38		29.4

Creole Gap

Date	Chlorine Cl- p.p.m.	Dissolved Solids p.p.m.	Suspended Solids p.p.m.	pH	Temperature Degrees C.
12 Feb.	7,300	14,780	19	----	----
14 Mar.	150	434	157	8.07	13.1
12 Apr.	6,100	13,006	7	8.00	19.2
25 July	14,250	29,270	27	----	29.2

Oyster Bay

14 Mar.	270	642	150	8.06	13.6
12 Apr.	4,700	9,454	7	8.00	19.7
25 July	13,000	24,608	22	----	28.9

Brickbat Reef (Three Mile Bay)

11 Feb.	9,500	18,030	29	----	----
14 Mar.	260	626	126	8.06	----
12 Apr.	3,600	7,232	65	7.90	19.2
25 July	13,250	26,890	58	----	28.9

Bay Boudreau

11 Feb.	8,300	16,310	113	----	----
12 Apr.	3,950	7,890	66	7.83	----
24 July	11,250	23,048	20	----	30.0

West Karaho Bay

11 Feb.	10,600	20,780	83	----	----
14 Mar.	690	1,426	71	7.82	----
12 Apr.	4,400	9,074	19	7.80	19.2
25 July	14,000	28,712	46	----	28.9

Cranetown Bay

11 Feb.	11,000	22,200	69	----	----
14 Mar.	910	1,852	70	7.77	----
12 Apr.	5,400	12,392	32	7.92	19.4
25 July	14,750	29,164	72	----	28.9

Drum Bay

11 Feb.	13,300	27,030	5	----	----
14 Mar.	770	1,578	96	7.83	15.0
12 Apr.	5,150	10,894	27	7.80	19.7
25 July	14,750	28,104	30	----	28.9

Morgan Harbor (Point Comfort)

11 Feb.	12,900	25,970	164	----	----
14 Feb.	1,410	2,770	78	7.05	15.0
12 Apr.	3,700	7,584	43	7.77	20.2
25 July	14,750	28,140	23	----	28.9

Observations on Spawning and Larval History of the Shrimp, *Penaeus setiferus* (L.)*

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* This paper is based on investigations made during a single visit of some months to Port Aransas. There are several points which I should have liked to do over again and some observations which are not fully clarified, but as Texas is far away from Europe as well as from Java, I have been prevented by other duties from bringing this paper to a final form for publication. However, as it has been found that some results of interest were obtained, Mr. Martin D. Burkenroad and Dr. Gordon Gunter kindly revised and annotated the paper, for which I hereby give my best thanks. The following shows that further investigations are needed, and I believe that some of the differences in the described larvae in literature have to be explained by varying ecdyses within the larval life.

INTRODUCTION AND ACKNOWLEDGMENTS

During my visit to the United States in 1948 I got an invitation from the Texas Game, Fish and Oyster Commission Laboratory in Rockport, Texas to study the larval history of the commercial shrimp, *Penaeus setiferus*. However, that location was impractical for laboratory work with the Gulf larvae. The salinity was too low, and the temperature too high, as Rockport is situated on the mainland shore of Aransas Bay and with at least two hours sailing to the localities in the Gulf where the shrimp larvae occurred. This made it very difficult in the heat of the summer in a small boat to keep the plankton alive during transport to the laboratory.

Therefore, the experimental part was moved to the Institute of Marine Science of The University of Texas at Port Aransas. The main laboratory of the Institute is situated on pilings in Aransas Pass itself, a tidal inlet between the bay and the Gulf, only a short sailing distance out to the spawning localities. The boat and fishery equipment were supplied by the Game, Fish and Oyster Commission. In this way the work was carried out through the help and collaboration of both institutions and I wish here to express my sincerest thanks for all help and facilities given to me by Mr. J. L. Baughman at Rockport and Professor E. J. Lund, Dr. G. Gunter and Dr. J. W. Hedgpeth of the Institute of Marine Science at Port Aransas. Special thanks are due to Captain George Nava, without whose readiness and skill the investigation could not have been carried on. It must here be remembered that the Gulf, especially in this westerly corner outside of Port Aransas, is often in the early summer a very rough and capricious sea.

I also want to thank Mr. John C. Pearson, Washington, D. C., who kindly gave me a copy of a translation of Hudinaga's (1935) paper.

For economic support during my stay in the United States and during subsequent study of the material I am indebted to the following Danish Foundations: the Rask-Ørsted Foundation, the Carlsberg Foundation, the Carlsen Lange Foundation and to Lohmann Rasmussens Memorial.

LOCUS OF SPAWNING

Spawning takes place in the open ocean and young swimming larvae move into the bays where the growing shrimp are later found. Burkenroad (1934b, 1939) supposes that spawning takes place to the seaward beyond the limits of the commercial fishery at that time (15 fathoms). Pearson (1939) finds confirmatory evidence from larval collections. This stand is contrary to Weymouth, Lindner and Anderson (1933) who believed that the shrimp spawn inshore and die after spawning.

My first task was to locate the spawning place of the shrimp in south Texas. Opinions on the location for the spawning were different among the different investigators and the local fishermen. It is generally known that in the spring large schools of sexually ripe males and females are found a few miles offshore where they are the subject of an intensive fishery during the weeks they stay here.

In 1948 the adult peneids were starting to appear in large numbers along the shores in the beginning of May. They were at that time standing in large schools from about half a mile from the shore and out to six to eight miles offshore, where the depths were about 20–25 m.

The shrimp were not quite ripe when they first arrived, but at the middle of May most of the females were with large ripe eggs nearly ready for spawning. Some of these ripe females and males were caught in the shrimp trawl and carried alive back to the laboratory in Port Aransas. Some of the females spawned in the containers in which they were kept during the trip back to the laboratory.

Shrimp with ripe gonads were placed in aquaria of approximately 200 liters supplied with running water from the Pass by a pump, ten in each aquarium, five females and five males. During the first night most of the females spawned.

Shrimp can move fast if they want to, so that the ripeness of those caught does not prove that they were on the spawning grounds; but I went out one night and stayed out fishing to the next morning, and found the adult shrimp at the same place as in the day time. This was only done for a single night.

I did not succeed in getting living females with attached spermatophores, but I once found a few dead ones in the trawl. Some females were also found with spermatophores torn off, although they had not yet spawned.

During this investigation I also found a few empty females with hard traces from dissolved spermatophores (Burkenroad, 1949), but as they may travel after the spawning, that does not give much information about the spawning grounds.*

**Editorial Note:* Females of *P. setiferus* with unripe ovaries, which are indicated to have spawned previously by the presence of spermatophore traces or left-over ripe eggs, may be found from February through October and are common in late spring and summer (Burkenroad, 1939, 1949, and unpublished). However, large numbers of developing ova are to be found in these ovaries, such as are not present in ripe ovaries (*cf.* the "recently spawned" ovary figured by King, 1948, Plate D, figs. 7, 8). Therefore, since the ovary of all "empty" females critically examined so far gives indication of some degree of re-ripening, it is not certain that *P. setiferus* has ever been seen within the first few days after spawning. A study of the rate at which re-ripening begins in shrimp spawned in captivity would be of interest.

The lack of any definite records of newly-spawned *P. setiferus* seems peculiar, especially when contrasted with the high frequencies of re-ripening females which show signs of having spawned on a previous occasion. A possibility worth consideration is, that females ready to spawn leave the inshore feeding grounds where the "schools" are concentrated. Scattered individuals of *P. setiferus* are sometimes taken by the *P. aztecus* fishery off Aransas Pass at depths considerably greater than those occupied by the schools of *P. setiferus* to which Heegaard refers. Such scattered shrimp, even though numerous, could at a time when the commercial fishery is concentrating on the inshore schools be located only through experimental trawling. This might account for the absence of newly-spawned shrimp in samples thus far examined (as well as for Heegaard's failure to encounter the first nauplius; see below).

I once tried to let the plankton net scrape the bottom just for a moment very smoothly. The net came up with one liter and a half of sand from the bottom. This sand was carefully examined in the laboratory and it was found to contain two eggs of a penaeid. Compared with the spawned eggs in captivity, they seemed most likely to be *Penaeus setiferus*. Ripe *Penaeus setiferus* were present in big schools above the place from where the sand was taken. The sand was standing in a glass on the deck of the boat and its temperature rose considerably during the voyage on the way back to the laboratory. Both eggs were in the blastula stage when they were discovered during the examination of the sand, but they were both dead. Although the plankton net was used nearly every second day, this was the only time *Penaeus* eggs were found among the catch.

Sand taken from the bottom by the trawl measured 0.35 mm. in diameter, but only a few measurements were made. The eggs were 0.27 mm. in diameter, so the sand grains were somewhat larger than the eggs. The eggs are heavier than sea water. They can only be swept from the bottom by heavy stirring, and sink immediately again when

this ceases (as also inferred by Burkenroad, 1939, and observed in *Penaeus* by Heldt, Hudinaga and Pearson). They would thus be difficult to collect.

The plankton was taken in a one meter silk ring-net. A one liter glass bottle was fastened at the bottom. The net was 5 m. long and little plankton was washed back out of the net as often happens with a shorter net.

Hauls of only five to ten minutes duration were made so as to keep the plankton alive. Most of the plankton was not preserved but taken alive into the laboratory and there some of the penaeid larvae were sorted out. For this reason I do not have any exact number of penaeid larvae of each haul, but in some there were more than a hundred.

The plankton was taken outside of the tidal inlet, Aransas Pass, at different distances from the shore. Often eight to ten hauls were made each fishing day. The larvae were taken in the plankton on the following days during my investigation in 1948 (the large intervals with no catch were largely caused by bad weather, in which it was not possible to go out with the small craft at my disposal). The hauls were taken regularly from the middle of April.

May: 20.29.31.
June: 3.14.15.16.17.29.30.
July: 1.6.7.8.13.

Nauplius were found on	20/5.31/5.3/6.15/6.17/6
Protozoea	29/5.31/5.3/6.14/6.15/6.16/6.17/6
Mysis	3/6.15/6.16/6.17/6.29/6.30/6.1/7.6/7.7/7.8/7
Postmysis	29/6.30/6.1/7.6/7.8/7.13/7.

From this it can be seen that there is a rather clear succession of the stages in time.*

**Editorial Note:* It hardly seems probable that larvae from eggs spawned off Aransas Pass would be able to persist in the same spot against the currents for a month. Indeed, it seems probable that *Penæus* spawnings are so located that drift will favor placement of the postmysis stages two weeks or so later in the proper position to be carried into the bays; and it seems quite possible that the young which enter the passes are in general not derived from eggs spawned in the vicinity.

Postmysis larvae of three species of *Penaeus* enter Aransas Pass, and those of both *P. setiferus* and of grooved shrimp have been taken in the Pass considerably earlier as well as later than the dates given by Heegaard for 1948. It should be noted that the specific identity of Heegaard's postmysis larvae is not known with certainty, and his first protozoea is not *Penaeus*.

Even if the nauplii were of *P. setiferus*, the earliest stage described by Heegaard may have been from 6 to 12 hours past hatching and from 30 to 40 hours past the laying of the egg, so that considerable drift from the point of spawning might have occurred (especially if *P. setiferus* spawns off the bottom as described for *P. japonicus* by Hudinaga, 1942).

The interval of 39 days between Heegard's first collections of nauplii and of postmysis, and the interval of 12 days between the last collection of protozoea and the first collection of postmysis, both seem excessively long. Pearson (1939, p. 30) concludes that "It appears logical to assume . . . that the young of *P. setiferus*, spawned offshore in late March and at the beginning of the spawning period, reach the estuarine waters as planktonic postlarvae in early April. . . ." Heldt (1938, pp. 69, 89, 100, 144) indicates less than 15 days from spawning to first postmysis of *P. trisulcatus* at 20° C. (probably a good deal less at higher temperatures). Hudinaga (1942, pp. 321, 330, 331, 336) indicates 12 days from spawning to first postmysis in *P. japonicus* at 27–29° C., under favorable rearing conditions.

Altogether, the significance of Heegaard's succession of stages seems unclear. These larvae may have been drifting through the Aransas Pass area after origin elsewhere.

Up to the Mysis stage the larvae were specially found in a narrow zone five miles offshore in 20 meters of water. Although I took plankton hauls not only on the locality where the adult shrimp were found, but on a line both towards the shore and further offshore up to several miles, I never caught a single larva at stations farther offshore than where the adult shrimp were taken.

The larvae were always thickest just above the bottom where they were taken on some occasions in large numbers. The second Mysis stage has strong swimming fans on the pereiopods and a larval statocyst and because of these the larvae seem no longer to be so absolutely at the mercy of the currents, but can partly move more or less independently. They also seem to stand more in swarms than the younger stages do. In this stage there begins the real wandering towards the shore and through the passes and into the bays behind the barrier islands. The bays are sometimes reached in the second Mysis stage, but generally the first to enter are the Postmysis larvae of the first or later stages. All the earlier larvae than second Mysis were taken out in the open Gulf.

We have thus three facts: The females ripe for spawning as well as males with ready spermatophores were numerous around five to six miles offshore. Nauplii were found at the same place some days after the moment when the females through examination were found to be absolutely ripe for spawning. Last, the sand sample which contained the two eggs was also taken at the same locality. All this seems to point towards the conclusion that *Penaeus setiferus* spawns immediately outside the coast at a distance of five to six miles from the shore.

In Louisiana, where Burkenroad's investigations took place, conditions are somewhat different, partly because the Mississippi River here pours great masses of fresh water into the Gulf; and spawning might take place considerably farther offshore in that region (*cf.* Pearson, 1939, p. 26).

The question may be raised whether possibly a spawning of *Penaeus setiferus* had taken place earlier in the year, since the spawning here mentioned in May-June was relatively very late.

Weymouth, Lindner and Anderson (1933) and Pearson (1939) have been convinced that the main spawning occurs in early summer and that a year elapses before *P. setiferus* is full grown and mature. Gunter (1950) says there may be two separate periods of successful spawning, one in spring and the other in the late summer; and (p. 20) that shrimp born in September might reach maturity the following April and their offspring might in turn mature in September, which means that there might be two generations in a year. If an early spring spawning had been the case in 1948, it should be expected that the larvae from this earlier spawning would be found in the bays, since there were none of them in the sea. The bays were therefore investigated for Penaeids with plankton nets and shrimp trawls, as early as April, but gave no results. Therefore, the products of earlier spawning can not have been there in any numbers. A castnet was also used in shallow water. This net gave a few half grown penaeids, but they were all *Penaeus aztecus.*

On July 10 to 12 the three bays around Rockport were again investigated: San Carlos Bay gave no penaeids and the same was the case with Mesquite Bay. In Cedar Bayou Pass, which leads into Mesquite Bay, I found a few Penaeids of an average length of 80 mm. Of 137 specimens examined 135 belonged to *Penaeus aztecus* and only two *Penaeus setiferus* were found. This shows clearly that in the present year there had not been any previous spawning of *Penaeus setiferus;* because if there had been an earlier spawning, the larvae from that spawning should have been found in the lagoons or out in the Gulf.*

**Editorial Note:* In the spring of 1950 and 1951, postmysis larvae of both *P. setiferus* and grooved shrimp were taken in Aransas Pass when first searched for in April; and previously spawned adults of *P. setiferus* were also present in commercial catches outside the Pass during

this month (Burkenroad, unpublished). Gunter (1950, pp. 14–18) found young *P. setiferus* of less than 23 mm. suddenly appearing in minnow seine and trawl catches in Aransas and Copano Bays in June, 1941, and May, 1942. Shrimp of such small sizes became scarce again in mid-summer and reappeared in late fall. Therefore, 1948 may have been an unusual year. It should, however, be noted that lack of young shrimp in the Bays may result from lack of successful colonization, not necessarily from a lack of spawning off the Pass.

It should also be observed that young *P. setiferus* have at times been hard to locate in the Rockport region during the recent years of drought, even when persistent search or subsequent catches have disclosed their presence.

Adult penaeids disappeared from the shores around the middle of June in 1948. Weymouth, Lindner and Anderson (1933) propose that they die after the spawning, contrary to Burkenroad (1934b, 1939, 1949) and King (1948) who are of the opinion that the same shrimp can spawn more than one time. The shrimp I had in captivity always died within a day or two after the spawning, except for one; but it must be remembered that they were kept under unfavourable conditions, so that exhaustion after spawning easily could be lethal in my captive specimens in cases where they possibly would have survived this critical period in their life in nature.

DEVELOPMENT

Eggs spawned on the way from the trawling-grounds to the laboratory were unfortunately always unfertilized. Females and males were placed in boxes of bolting cloth with wood frames and suspended in the waters of Aransas Pass, but these failed to live. In the laboratory some of the ripe females and males were placed in large aquaria with running water and a filter at the drain for catching eggs. Next morning the bottom of the aquarium was strewn with the small eggs, with a diameter of 0.27 mm. to 0.31 mm., average 0.28 mm. The colourless egg membrane is included in this measurement. The colour of the yolk was orange or yellow brown to light olive green.*

**Editorial Note:* Neither Burkenroad nor Gunter have, in an extensive experience, seen ovaries of *P. setiferus* with a green tinge, although this color has been reported not only by Heegaard but by King (1948). In *P. aztecus* the living ripe ovarian eggs are blue-green (printed by Burkenroad, 1949, through an unfortunate slip, as "yellow").

Since there is some question whether the eggs attributed by Pearson (1939) to *P. setiferus* may not have been those of *P. duorarum*, it is interesting that he describes the shell as having "a characteristically purplish-blue color in reflected light under the microscope," in contrast to Heegaard's "colourless."

Eggs which were spawned in the aquaria as well as those spawned in the containers during the transport of the shrimp to the laboratory all started cleavage, although only the first few divisions were regular (figs. 1–5) and they soon became more and more irregular and finally stopped. They were probably unfertilized.

To get fertilized eggs I tried to put ripe males and females together in the same aquarium, as well as in the previously mentioned boxes. The last were placed directly in the Pass underneath the laboratory, but both experiments failed.

I also squeezed spermatophores out of ripe males, crushed them and shook them with newly spawned eggs, as well as with eggs pressed out of ripe females in the same way as salmon are stripped, but all experiments failed. Also a few drops of sodium hydroxide were dissolved in the water to activate the spermatozoa, all without success (*cf.* Burkenroad, 1947, on fertilization in decapods).

It was therefore necessary to study development from planktonic material. Planktonic eggs could not be obtained and the larvae were not reared in the laboratory, so the stages described are those found in the net.

The diameter of the laboratory-spawned eggs (including membrane and pervitelline space) is only from 0.27–0.31 mm., average 0.28 mm., and the earliest Nauplius stage collected is about 0.32 mm. in body length. However, one must hold in mind that the Nauplius of some crustacea absorbs water immediately after hatching and thereby grows rapidly for the first hour or so after it is hatched (Heegaard 1947, p. 44). Also, another point might permit the assumption that the youngest larva seen (fig. 6) represents the first Nauplius stage, and that is that the whole body is very embryonic, with no trace at all of internal organs except the muscles of the antennae. Inside the cuticle the whole is filled up with yolk globules; further, the appendages present are not yet jointed and the larva is nearly unpigmented compared with the later stages. Even the eyes have very little pigment, which shows that development has only taken place for a short period. Taking this into account, it seems that if there is a previous free Nauplius stage, it ought to be very short.

However, I did not find the first Nauplius stage as it is described by Heldt (1938). The difference between her first Nauplius and mine lies mainly in her description of hairs on the setae; she found the setae on the first antenna in the first Nauplius stage smooth and I found a few short hairs. These hairs can lie so close to the setae that the light in the microscope has to be just right to enable one to recognize them in my youngest stage.*

**Editorial Note:* Heldt, Hudinaga, and Pearson are in agreement, not only that there are no barbs on the setae in the first free nauplius, but that there are only five setae on the exopod of the second antenna in this stage, the sixth being added in the second stage (reared from the egg by these investigators). Since Heegaard's planktonic "Nauplius I" not only has barbed setae but, according to his figures, has six setae on the exopod of the second antenna, there is considerable doubt that he found the first nauplius. We have therefore here listed his tabular account of "Nauplius I" under the heading *Nauplius II.*

According to Heldt (1938) and Hudinaga (1942), the first molt after the one accompanying eclosion does not occur for half a day to a day in grooved species of *Penaeus*, so the stage missed by Heegaard may have an appreciable life.

Nauplius II.	Figs. 6–7 length 0.32 mm; width about 0.15 mm.
Setae	Minutely barbed.
Labrum	Only bud-shaped; no mouth opening or anus.

LIST OF ABBREVIATIONS

A_1	First antenna	L	Upper lip, labrum
A_2	Second antenna	l	Lateral spine of carapace
a	Anus	Lb	Lower lip, labium
ac	Alimentary canal	Md	Mandible
Ad	Abdomen	Mx	Maxilla
b	Basis	Mxp	Maxillipede
Br	Brain	NE	Nauplius eye
C	Carapace	P.	Protopod
c	Coxa	Pe	Pereiopod
E	Compound eye	Pi	Pars incisiva
Em	Egg membrane	Pl	Pleopod
En	Endopod	Pm	Pars molaris
Ex	Exopod	R	Rostrum
ex	Excite	S	Supra-orbital spine
f	Frontal organ	t	Telson
Fu	Caudal furca	U	Uropod
h	hepatic spine	v	Fronto-lateral corner of carapace

All measurements in figures represent 0.10 mm. All the figures are drawn with a camera lucida from single selected specimens. No figure is combined or composed of more than one specimen.

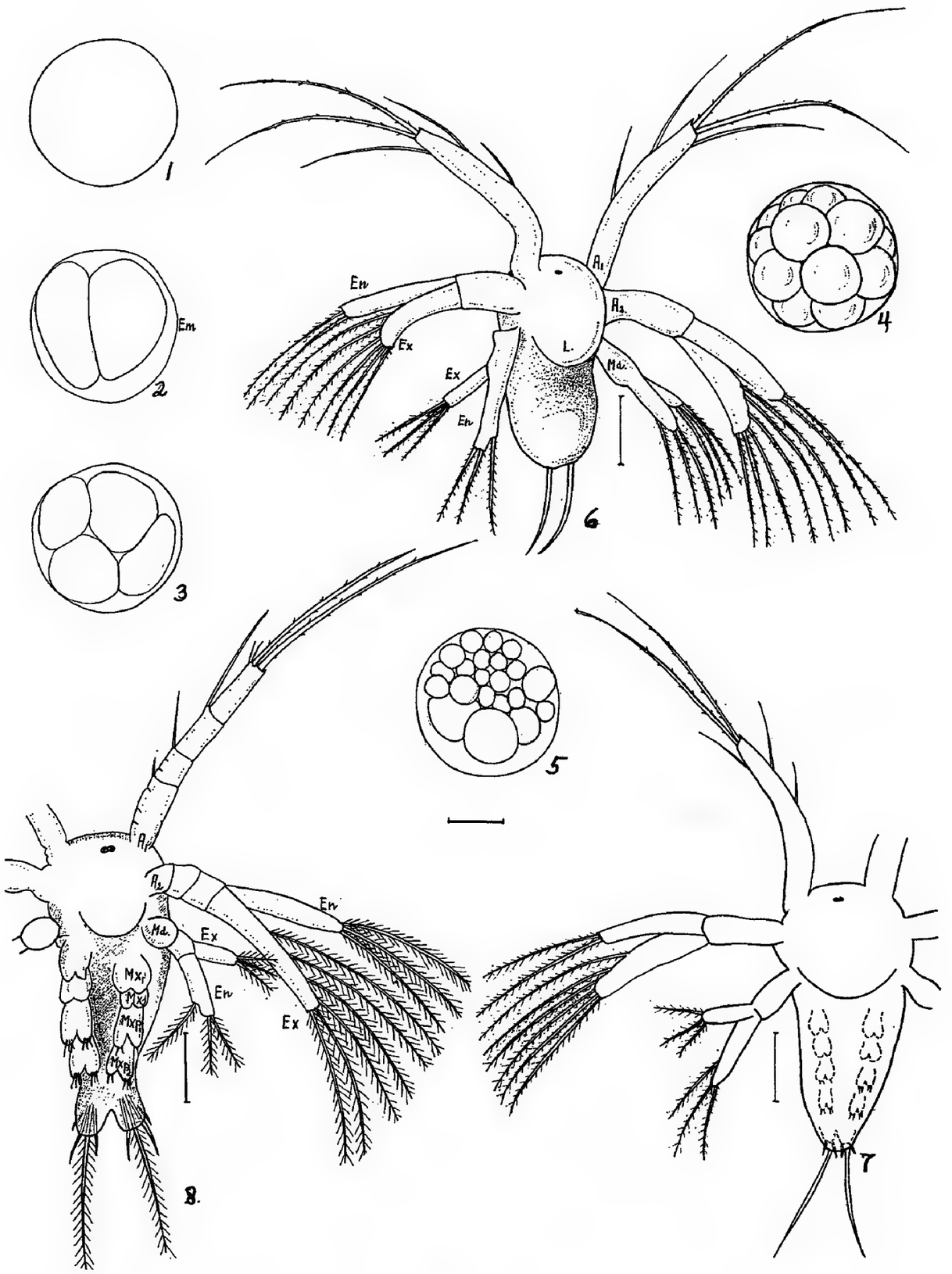

PLATE I

Egg, Nauplius and Metanauplius

Figs. 1–4 Development of eggs from spawning to Blastula.
Fig. 5 Gastrula unregular from an unfertilized egg.
Fig. 6 Second Nauplius from ventral:
Fig. 7 Same Nauplius some hours later. Parts of the following stage can be seen through the cuticle (stepulated line).
Fig. 8 Third Nauplius.

A_1	Unjointed, 2 terminal setae of unequal length; 2 med., 1 lat. shorter setae.
A_2	Bifurcate, stout unjointed protopod, unjointed exopod with 6 setae and endopod with 2 setae.
Md.	Bifurcate with unjointed Protopod, Exopod and endopod, in some specimens division between these three parts. No trace of corpus mandibulae. Exp. and Enp. with three setae each.
Caudal setae	2 smooth setae; no caudal furca.

Toward the end of this Nauplius stage, the next stage starts to take shape underneath the old cuticle (see fig. 7). It can be seen that the following Nauplius stage is a Metanauplius, as it has the four pairs of appendages following the mandibles. Underneath the cuticle of my late-stage earliest Nauplius small bifurcated limb-buds can be recognized in all in four pairs, which are the coming first and second maxillae and the first and second maxillipedes. My earliest Nauplius has a cubic posterior end, the rounded lines of which are only broken by the anal or furcal setae, but under the cuticle this part of the body, behind the limb-buds, the coming anal furca can be seen as two posteriorly directed buds in the posteriormost part of the body. These two buds, representing the two halves of the furca, are furnished with some stiff setae, which have already started to develop inside the cuticle of the first Nauplius. These new setae, which are rather stiff like spines, have little space for themselves inside the old cuticle and therefore project through on both sides of the anal setae of this first Nauplius stage, as can be seen in fig. 7.

It must here be mentioned, that the new Nauplius underneath the old cuticle is not only furnished with a larger number of spines and setae, which take up more space, but the body of the larva is pressed so hard against the old cuticle by the growth of the coming thorax and abdomen, that the whole body is a little elongated. By measuring this it can also be recognized that the larva has a smaller width in the posterior part of the body just before the ecdysis (as fig. 7) than shortly after the hatching, but at the same time it has reached a total length of between 0.35 and 0.40 mm.

Nauplius III (?)*	Fig. 8. Length 0.4 mm; width about 0.15 mm. less yolk; no internal organs can be seen.
Labrum	Partly free lobe projecting backwards, no mouth opening or anus.
Labium	No trace.
A_1	4 jointed; 2 terminal setae of unequal length and 2 tiny hairs and 3 med. setae.
A_2	Bifurcate; 3 jointed Protopod, Exopod and Endopod Exp. with 6 setae Enp. with 3 setae.
Md.	Bifurcate with unjointed Protopod, developing Corpus mandibulae Exp. and Enp. with 3 setae each.
Mx_1, Mx_2 Mxp_1, Mxp_2	Bifurcated buds; Mxp_{1+2} tipped with tuft of embryonal setae.
Caudal Furca	Present, each lobe with 4 setae.

**Editorial Note:* This nauplius with four pairs of caudal spines, described by Heegaard as the "second," shows many differences of detail from any of Pearson's series. In particular, the number of caudal spines given by Pearson increases from three pairs in his third nauplius to five pairs in his fourth nauplius. Since Heegaard makes no direct comparison with Pearson, the significance of the differences is difficult to judge. Since Heegaard shows only three pairs of caudal spines under the cuticle of his late "Nauplius I" (Nauplius II), it does not seem entirely sure that his "second Nauplius" with four pairs of spines was derived from his "first" by a single molt. We have therefore headed the tabular account *III (?)*.

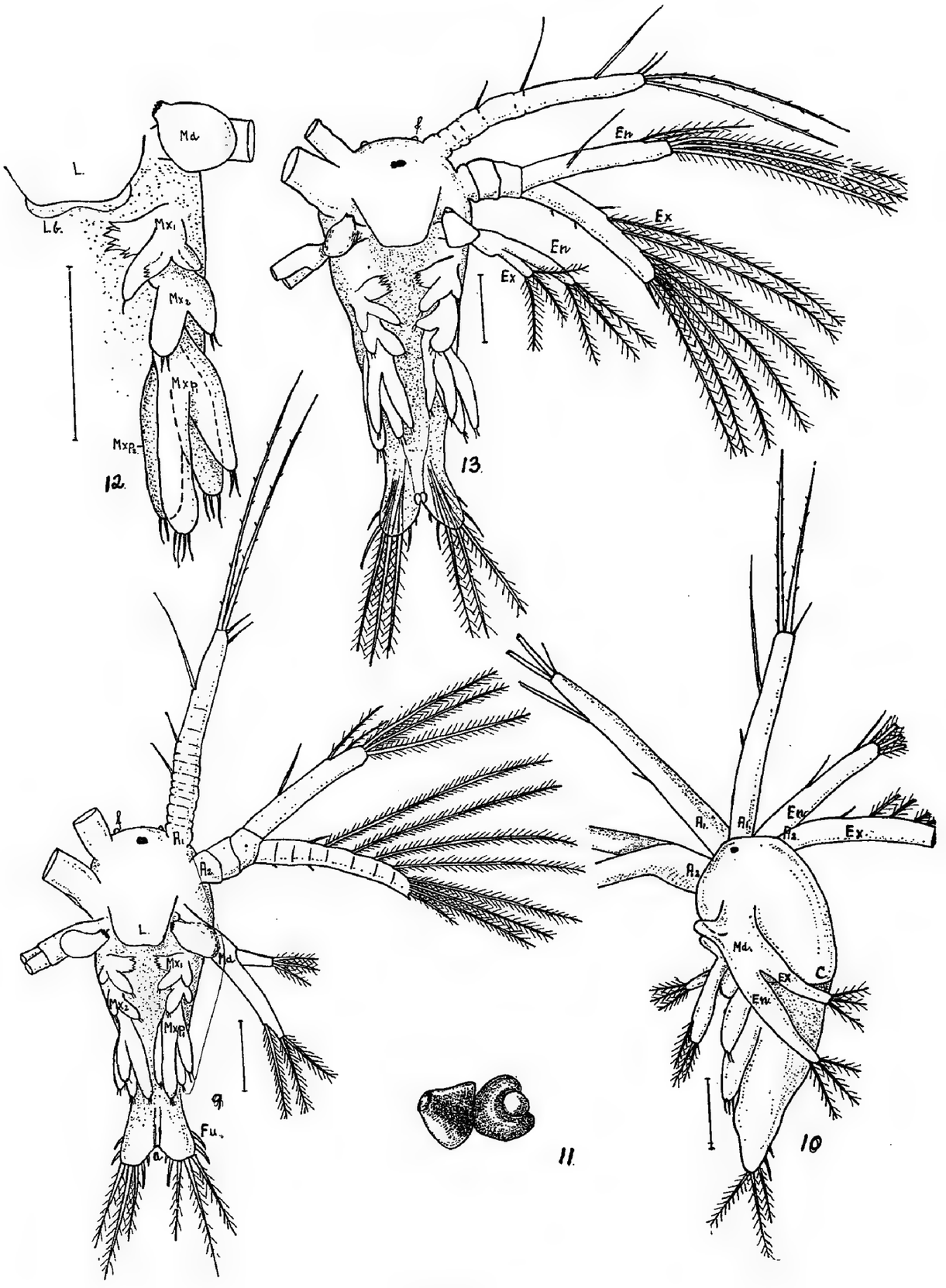

PLATE II

Metanauplius

Fig. 9 Last Nauplius from ventral.
Fig. 10 Same from lateral.
Fig. 11 Detail of Nauplius eyes.
Fig. 12 Detail of appendages on the left side.
Fig. 13 Last, large specimen.

*Last Nauplius**	Figs. 9–13. Length 0.45 mm; width about 0.2 mm.
Frontal Organs	Present.
Labrum	Large squarish lobe.
Labium	Started to develop with two lobes.
A_1	Distinct 4 joints disappeared, but subdivided into several secondary joints, setae as previous stage.
A_2	3 jointed Protopod; Endopod unjointed; Exopod subdivided into secondary joints. Enp. with 3 terminal setae and 3 medial setae. Exp. with 8 setae and 1 medial; 2 lateral shorter setae.
Md.	With further developed Corpus mandibulae. Exopod and Endopod vestigial, but still with 3 setae each partly empty.
Mx_1 Mx_2	With large gnathobase (fig. 12).
Mxp_1 Mxp_2	With elongated Exopod and Endopod.
Caudal Furca	Each lobe with 7 setae.

**Editorial Note:* Heldt, Hudinaga, and Pearson are agreed that *Penaeus* nauplii reared by them do not achieve seven pairs of caudal spines before the final stage (fifth, sixth or eighth). Since Heegaard gives no evidence for the derivation of his planktonic seven-spined stage from his planktonic four-spined stage at a single molt, we have substituted the present neutral terminology for his "Nauplius III."

Whether this nauplius (or the earlier ones) is correctly referred to *Penaeus* cannot be regarded as entirely certain, since Heegaard's first protozoea is evidently of another genus, and since the nauplius differs in certain details from any reared by other workers. In particular, Heegaard shows remarkably short mandibular setae and middle seta of caudal furca (*cf.* Pearson, 1939, fig. 7). The caudal spines observed by previous investigators were minutely barbed, not plumose, etc.

Although the nauplii of Penaeinae display specific differences, generic distinctions among them seem hard to draw. *Xiphopeneus*, a form related to *Trachypeneus*, is fairly common in the Gulf off Aransas Pass in depths of less than 10 fathoms, and is ripe in spring and summer. Its larvae have never been identified, and it might well be the parent of Heegaard's first protozoea. It seems by no means impossible that Heegaard's nauplii might belong to the same genus as his first protozoea, even though the general appearance of these nauplii is *Penaeus*-like.

There has been some divergence of opinion concerning the frontal organs in Nauplii and Protozoeal stages of Penaeids. Fritz Müller (1863, p. 11) describes them as "halbkuglig vorspringendes Knöpfchen über den Stirnrand" in the old Nauplius. Hudinaga (1935) found them first in the first Protozoea in *Penaeus japonicus*, Heldt (1938) found them in the last Nauplius as well as the Protozea of *Sicyonia carinata*, but not before the first Protozoea stage in the two other penaeid species she studied (*Penaeus trisulcatus*, *Parapenaeus longirostris*). Pearson (1939) found frontal organs in his fourth and fifth Nauplius stage of *Penaeus setiferus* (pp. 12–13), but in the first Protozoea he states that they are lacking (p. 14). In accounts of other species he does not mention frontal organs, but figures them in the first Protozoeal stage of *Trachypenaeus constrictus* (fig. 40), *Parapenaeus longirostris* (fig. 47), and in *Eusicyonia stimpsoni* (fig. 62).

As can be seen on figs. 9 and 13 in this paper I found them in the last Metanauplius stage of *Penaeus setiferus* as two small bulbs between the first pair of antennae. Probably they are not functional before the first Protozoea stage, where they become much larger and seem further developed.

In the middle line a little behind the frontal organs on the dorsal side the Nauplius eyes are placed (fig. 11). They are of the typical shape and paired, consisting of two cups with the back turned towards each other and a lens placed in the depression.

The internal organs have started to develop. The digestive channel can be seen most clearly near the mouth and the anus which both are closed to the exterior. The middle

of the body is still filled up with yolk globules. The beginning of a hepato-pancreas and a heart have developed. Various features show that this is the last Nauplius stage, some of the characters of the coming Protozoea stage having already started to show through the cuticle. On the dorsal and the lateral side of the body the posterior margin of the coming carapace can clearly be seen as a line underneath the cuticle a little behind the mandibles in line with the second maxilla on the lateral and dorsal side of the larva (cf. fig. 10).

Discussion of the Number of Nauplius Stages:

Not only the number of Nauplius stages, but the whole number of penaeid larval stages differs very much in different accounts found in the literature. Below (Table I) is a list of the number of Nauplius stages in the different species investigated by the different authors. From this it can be seen that the number of stages appears to differ between the different investigators rather than from genus to genus.

Table I

Number of Nauplius stages in members of the family Penaeidae, from the literature*

Species	No. of Naupliі	Author
Penaeopsis stebbingi	3	Gurney 1927
Penaeus japonicus	6	Hudinaga 1935
Penaeus trisulcatus	8	Heldt 1938
Parapenaeus longirostris	8	Heldt 1938
Sicyonia carinata	8	Heldt 1938
Penaeus setiferus	5	Pearson 1939
Trachypenaeus constrictus	5	Pearson 1939
Eusicyonia stimpsoni	5	Pearson 1939
Sicyonia wheeleri	3	Gurney 1943
Penaeus setiferus	3	Heegaard (above)

**Editorial Note:* To this series may be added *Metapeneus monoceros* and *M. affinis*, both listed as having six nauplius molts by Hudinaga (1942, p. 323), who gives a table similar to Heegaard's. Heldt, Hudinaga, and Pearson do not specifically state that they have secured 5, 6 or 8 molt-skins from a nauplius isolated at hatching. However, Heldt does say (1939, p. 44), "L'étude des formes larvaires fut faite à la fois sur le matériel fixé et sur les mues obtenues"; and, given the well-spaced tempo of moltings which she indicates, the minimal number of stages should have been clearly marked even in mass rearings by the number of occasions on which quantities of cast skins appeared in the container. Therefore, Heegaard's inclination in favor of only three (or four) nauplius molts seems to require more evidence than can be obtained from planktonic material; even though it may be granted, in conformity with the implications of Table I, that the number of naupliar molts in the different species seems uncertain.

It seems very unlikely that *Penaeus trisulcatus* should have eight Nauplius stages, while *Penaeus japonicus* six, and *Penaeus setiferus* has three or five Nauplius stages; or that *Sicyonia carinata* should have eight stages in the Nauplius but *Sicyonia wheeleri* only three. Although it is known in some insects that different races of the same species have different number of larval stages, as for instance in the silkworm, this is not known in the Crustacea.

The difference between nauplius stages of *P. setiferus* consists of small differences in the size and partly the number of setae. Pearson's Nauplius III has acquired from the previous stage a small terminal seta on the exopod of the second antenna making a total of 7. I have found 6 setae in my stage I-II [identified by the editors as II and III] and 9 setae in my stage III [identified by the editors as Last], but in some specimens a variation from this is found.

It may be a possibility that the development of maxillae, maxillipedes, and furca with furcal spines, all inside the first Nauplius cuticle except for the points of the

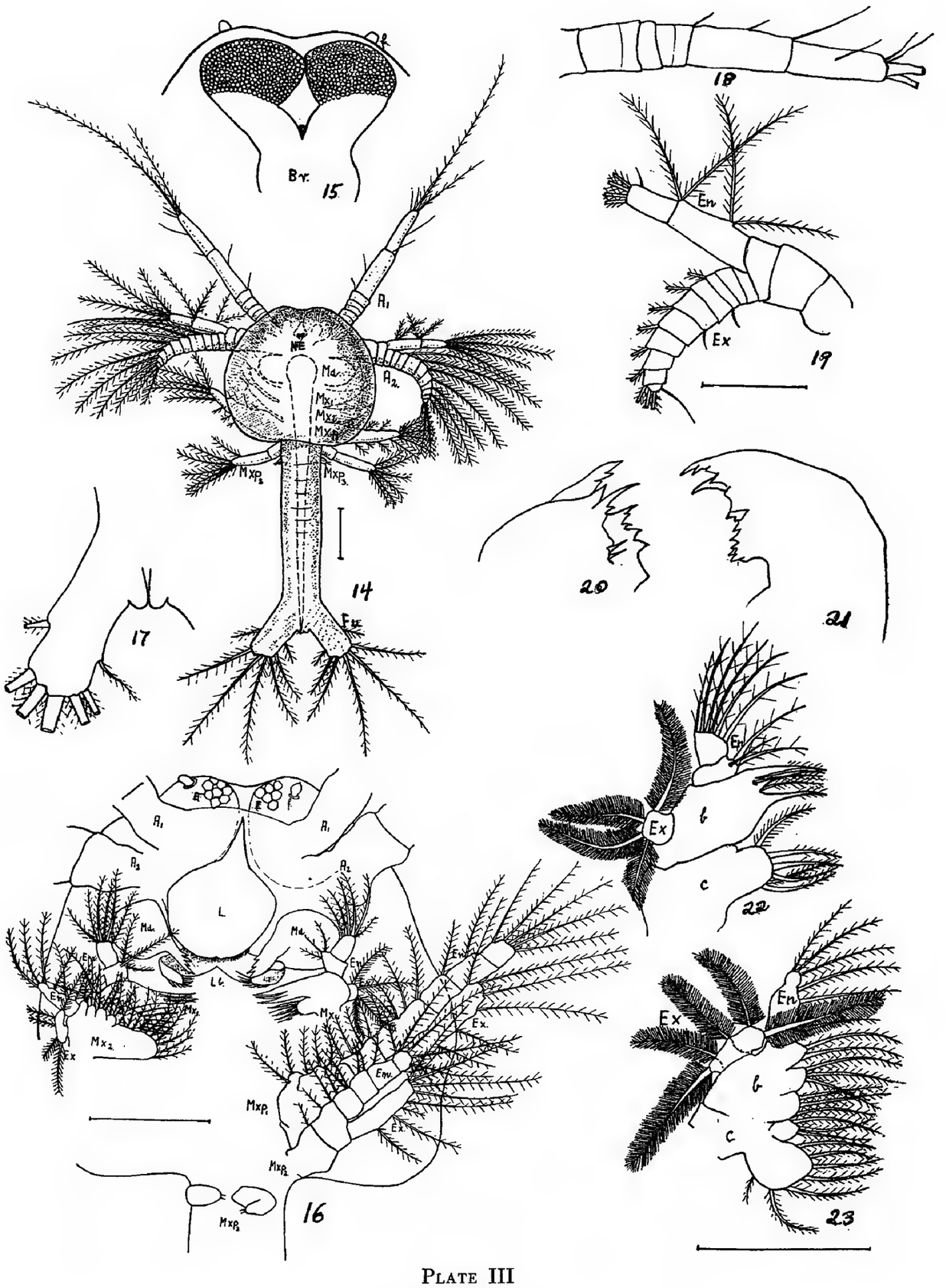

PLATE III

First Protozoea

Fig. 14 First Protozoea from dorsal.
Fig. 15 Detail of the compound eyes and Nauplius eyes.
Fig. 16 Cephalothorax with appendages from ventral.
Fig. 17 Left side of caudal furca.
Fig. 18 First antenna.
Fig. 19 Second antenna.
Figs. 20–21 Mandibles.
Fig. 22 First maxilla.
Fig. 23 Second maxilla.

spines, may account for some of the higher numbers of Nauplius stages which have been described by some of the previous investigators of Penaeid larvae (see also the section on the Third Protozoea, below).

*First Protozoea**	Length 0.7 mm. Fig. 14–23.
Carapace	Globular, diameter 0.3 mm, no spines, covering backward towards 3 thorax segm.
Thorax	Length 0.3 mm; width 0.1 mm, weakly segmented.
Abdomen	Length and width as thorax but unsegmented.
Caudal Furca	Flattened with 7 setae on each branch (fig. 17).
Frontal org.	Fully developed.
Eyes	1 pair of Nauplius eyes still present, pair of compound eyes developed underneath carapace (figs. 14–15).
A_1	7 jointed; 2 terminal setae of unequal length and 2 tiny hairs 4 med. setae (figs. 14–18).
A_2	Protopod 3 jointed; Endopod 2 jointed with 4 terminal setae and 1 hair 4 medial setae in 2 pairs from notch characteristically placed. Exopod 10 jointed; 1 medial seta on joint 3–9 and 3 setae on joint 10 laterally 1 short seta on joint 3 and 5; (fig. 19).
Labrum	Globular with anterior pointing spine, posterior small medium notch and fringe of hairs.
Labium	Cleft nearly to the base with 2 flattened lateral lobes with stiff setae.
Md.	Only Protopod with corpus mandibulae left. Right and left md. never symmetrical, but no preference for right or left. Incisor part more developed than molar part in general. (figs. 16, 20, 21).
Mx_1	Protopod 2 jointed with strong endites. Endopod 2 jointed, Exopod unjointed with 4 very plumose setae. (fig. 22).
Mx_2	Much like mx_1 but stronger with no distinct division between Coxa and Basis. Endopod can be 1, 2, or 3 jointed (see discussion pp. 31, 36, 40). Exopod with 2 sutures and 5 plumose setae. (fig. 23).
Mxp_1 Mxp_2	Well developed bifurcate swimming appendages Protopod 2 jointed, Exopod unjointed; Endopod 4 jointed. (fig. 16).
Mxp_3	A small bud or missing.

**Editorial Note:* Heegaard's Figure 14 differs conspicuously from the first protozoea of *Penaeus* as reared and described by Heldt, Hudinaga, and Pearson, in the following features of systematic importance:

(1) Endopod of second antenna much shorter than the exopod and the first antenna.
(2) Endopod of second antenna with two conjoint pairs of setae springing from the medial edge.
(3) Caudal notch angular.
(4) Third maxillipede present.

In the first three of these features, Heegaard's specimen closely resembles Pearson's *Trachypeneus* and *Sicyonia*, and it seems probable that it should be attributed to one of the species of those genera or to *Xiphopeneus*.

In comparison Pearson (1939) did not find frontal organs in the first Protozoea (discussed above). Gurney (1926) describes no seta on 4th exopodial joint of second antenna in *Penaeopsis stebbingi*, but saw setae on the 3rd and 5th joint. This could not be clearly seen by Pearson (1939) and was not found in my specimens. It is also unlikely to be the normal as the setae develop from the distal to proximal direction in the swimming fan joint by joint.

Both in this stage, as in the following stages, there are some minor differences in the number of setae between my specimens and Pearson's description, but in some

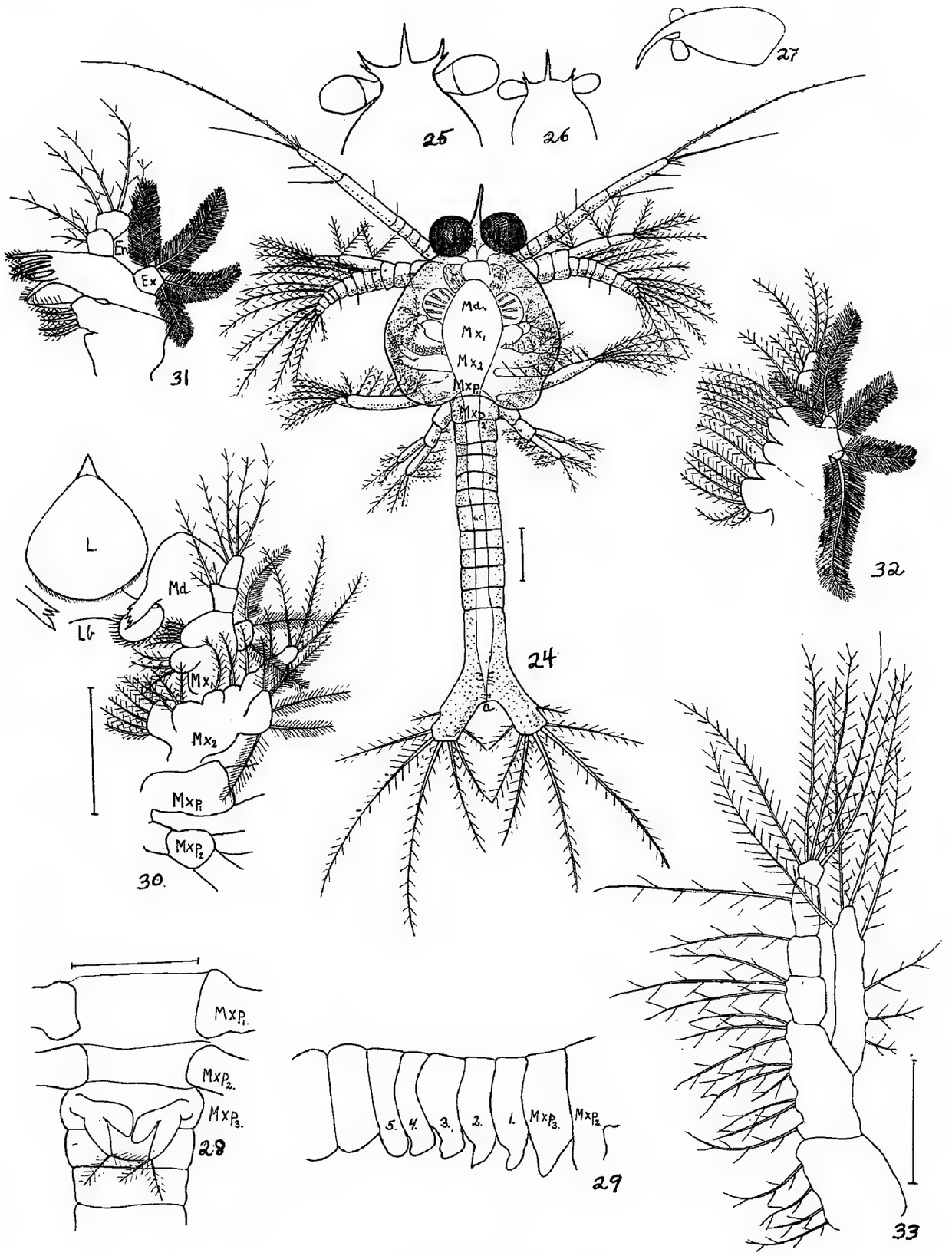

PLATE IV

Second Protozoea

Fig. 24 Second Protozoea from dorsal.
Figs. 25–27 Carapace.
Fig. 28 Last thoracal segment with maxillipedes.
Fig. 29 Thoracal segments of another specimen seen from lateral.
Fig. 30 The mouth appendages in their natural position.
Fig. 31 First maxilla.
Fig. 32 Second maxilla.
Fig. 33 First maxillipede.

cases there are differences within the specimens. Pearson saw only about 2 setae on the exopod of the first maxilla. The number in my specimens was constantly 4. In the second maxilla Pearson has only found 3 setae, I have constantly 6 setae. But in an examination as Pearson's where no exact figure was to be made some setae may easily be overlooked.

*Second Protozoea.** Length beyond 1 mm. Figs. 24–34.

Carapace	Length 0.5 mm. incl. rostrum; width 0.4 mm. or less with Rostrum and bifurcated supra-orbital spine, orbicular incarvation setting eyes free. (figs. 24–27).
Thorax	8 segments. Free thorax 0.2 mm.
Abdomen	5 to 6 segments. 0.3 to 0.4 mm.
Caudal Furca	Flattened with 7 setae on each branch. Anus opening in cleft of furca.
Frontal org.	Disappeared.
Eyes	Nauplius eyes still present, compound eyes free of carapace on small stalks.
A_1	Larger, but no structural change from previous stage.
A_2	No change except medial setae on joint 2–9, one more than Zoea I
Labrum	A little more triangular and no median notch (fig. 30).
Labium	Lateral lobes more rounded.
Md.	As in first Protozoea.
Mx_1	Endopod with less and weaker setae than Protozoea 1 (fig. 31).
Mx_2	Endopod 3 jointed.
Mxp_1 Mxp_2	Larger and of equal size but same number of joints and setae as in Protozoea 1
	(figs. 33, 34).
Mxp_3	Rudimentary, varying (figs. 28–39.

**Editorial Note:* Heegaard's figures 25 and 26 show the diagnostic bifurcated postocular spines of the *Penaeus* Protozoea (bifurcation overlooked by Pearson but present in his Louisiana specimens). However, in Heegaard's figure 24, postocular spines of peculiar form are combined with features reminiscent of Pearson's *Trachypeneus* and *Sicyonia*, which lack postocular spines in this stage. Among these features are the relative shortness and the two pairs of conjoint setae of the endopod of second antenna and the shortness of the carapace relative to the body length. The relatively strong development of third maxillipede shown in Fig. 28 is also reminiscent of Fig. 14.

Pearson (p. 17) describes the carapace as covering to the fifth to sixth thoracic somites; I have only seen it cover to the third segment, the third maxillipedes. He also (p. 18) says "Rudimentary buds of the pair of the third maxillipeds and the following five pairs of pereiopods are evident". This I have found to be right in some specimens, but not in all, because of variation within the stage.

A difference in development between the specimens in the same stage is shown better in this stage than in the previous ones. Figure 28 gives a part of the larva of figure 24 from the ventral, which shows the third pair of maxillipedes as bifurcated limb buds with two setae on each exopod, but none on the endopod. The following thoracic segments have no trace of limbs, as can be seen on the figure. But on figure 29, which also is of a larva in the second Protozoea stage, it can be seen that all the eight thoracal segments have developed limbs or limb buds. The following abdominal segments have no trace of limbs. This difference in development between the specimens all in the same larval stage is shown still more clearly in the next stage.

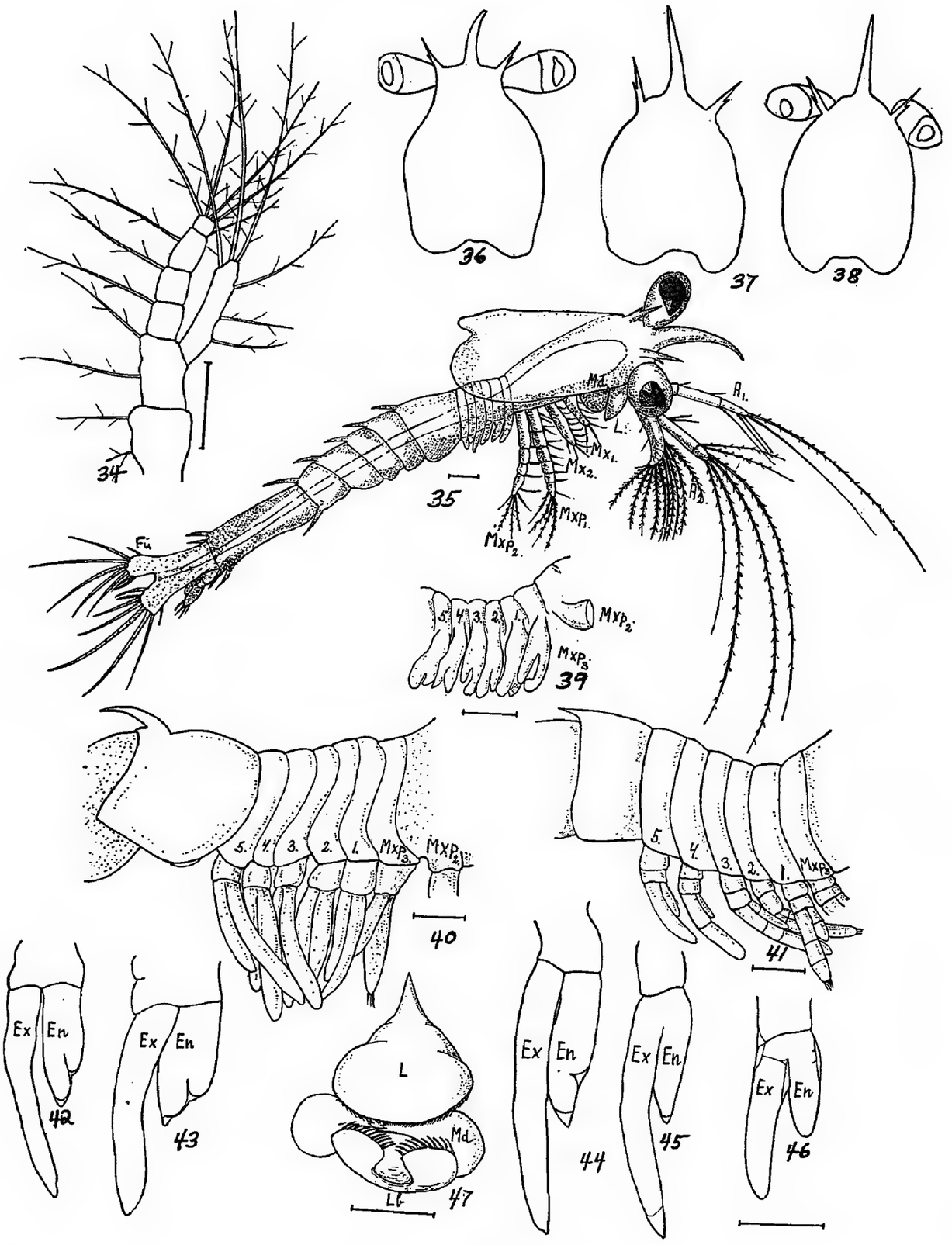

PLATE V

Third Protozoea

Fig. 34 Second maxillipede of second Protozoea.
Fig. 35 Third Protozoea.
Figs. 36–38 Carapace.
Figs. 39–41 Thoracal segments of specimens in different development, but all third Protozoea.
Figs. 42–46 Five pereiopods.
Fig. 47 Labrum, mandible and labium.

Third Protozoea.	Length about 2 mm. Figs. 35–60.
Carapace	Length 0.8–0.9 mm. incl. rostrum width 0.3 mm. covering all thoracal segments. (figs. 35–38).
Thorax	8 segments with budding limbs of variating development in different specimens (figs. 35, 39, 46).
Abdomen	6 segments, segm. 1–5 with 1 dorso-median spine on posterior margin on segm. 5 further 1 postero-lateral spine on each side. 6 segm. with 1 postero-lateral and 1 postero-ventral spine on each side (fig. 35).
Caudal Furca	Separated from 6th abdominal segment with 8 setae on each branch. Anus opening ventrally in middle of furcal plate (fig. 35).
Eyes	Nauplius eye still present.
A_1	5 proximal joints coalesced, following new joint 2 tipped with 2 short, 1 larger setae. 3 joint as before but longest distal seta still more elongated. (fig. 48).
A_2	Protopod 2 jointed (two first coalesced), distal joint with small spine; Exopod with 10 joints, 11 setae in the fan, 1 lat. seta on joint 3 and 5. (fig. 49).
Labrum	More elongated. (fig. 47).
Labium	Lobes more flattened and curved. (fig. 47).
Md.	Unequal and not meeting in middle line (fig. 47). Tooth further developed (fig. 55).
Mx_1	Constriction at base of protopod endites. Endopod 3 jointed. Exopod 2 jointed (fig. 55).
Mx_2	Endites more rounded with more setae. Endopod 4 jointed; (fig. 56).
Mxp_1 Mxp_2	Only minor changes (figs. 57–58).
Mxp_3	Bifurcate, varying (figs. 35, 39, 41).
Pereiopods	1–5 varying (figs. 35, 39, 46).
Uropod	Bifurcate (fig. 60).

In the third maxillipede and the five pereiopods there is great variation betweeen the specimens. In figures 35, 39, 40, 41 some examples of this variation are figured. In figure 35 merely limb buds are shown, but in figure 39 these are distinctly bifurcated, though not joined. In figure 40 a little further development has been reached. The limbs in this specimen have an undivided protopod and an unjointed exopod and endopod, except for the third maxillipede (fig. 59), in which the exopod is two-jointed and the endopod unjointed. Underneath the cuticle of the endopod five joints developing for the coming stage can be seen. Further, the endopod in this specimen was tipped with two embryonic setae. In the succeeding five pereiopods (figs. 42–46) the exopod was distinctly longer than the endopod. In the endopod of the three first pairs of pereiopods, the beginning development of the chela can be seen under the cuticle as a fissure running in a longitudinal direction. In the larval specimen of figure 41 the development has gone still further, the protopod is divided into both coxa and basis and even some of the exopods and endopods are jointed.

This shows us an interesting point in the development of *Penaeus setiferus* and probably all penaeids. It is the same picture as in the Euphausids (see Fraser, 1936; Heegaard, 1948), where, especially in the Furcilia stages, there is the same considerable difference in size and development in the same species taken at the same time and locality. Fraser had an enormous lot of material which showed the vast variety between the specimens in the same larval stage. This can only be explained in accepting the fact that no fixed stages occur, but as always will be the case because of external as well as internal factors, the specimens inside the same school grow with varying rapidity. However, because the old cuticle is shed with nearly the same intervals in

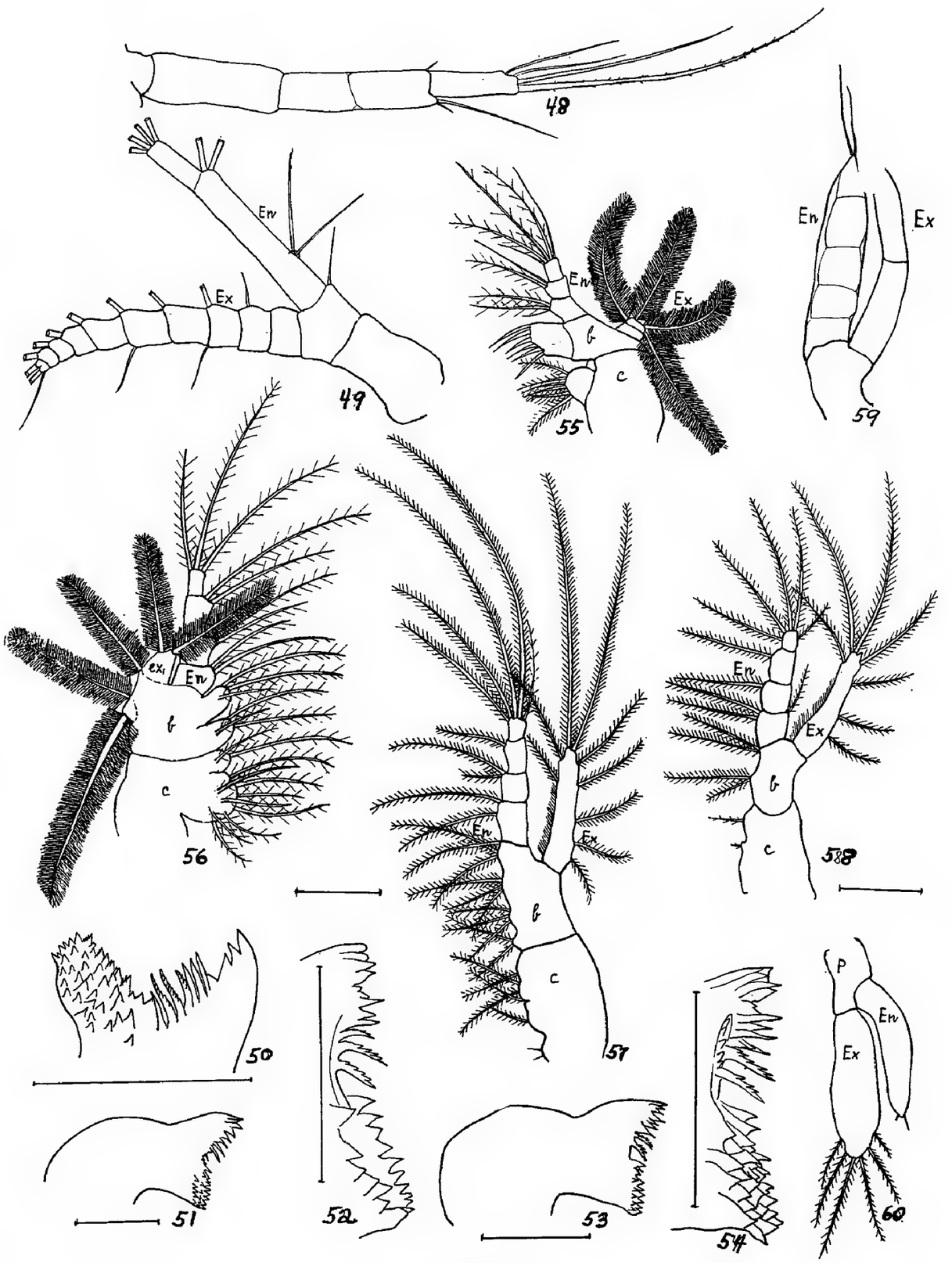

PLATE VI

Third Protozoea

Fig. 48 First antenna.
Fig. 49 Second antenna.
Figs. 50–54 Mandibles.
Fig. 55 First maxilla.
Fig. 56 Second maxilla.
Figs. 57–59 First—third maxillipede.
Fig. 60 Uropod.

all the larva, the different specimens will be not only of different size but will also be at a different point on the developmental curve when the ecdyses take place.

In the Nauplius stages and later in the development in the Mysis and following stages of penaeids differential development is difficult to ascertain without a great deal of material, because there is no major change from stage to stage; instead the larva is following a more continuous line of growing and development. In the three Protozoea stages distinct differences are present in the carapace, the rostrum, the placement of the eyes and the spines of the abdomen. It is here of interest to notice, that no investigator of penaeid larva has ever described more than three and in recent times always three Protozoea stages. To the contrary the number of Nauplius stages described are much divergent and the same holds for the stages after the Protozoea. But the general difference within these two groups of larval stages—Nauplii and Post-Protozoea—are only slight, consisting of size, number of joints and spines, developmental stage of pereiopods and pleopods. This suggests that some authors have described too many stages in penaeids on distinctions which only are individual differences, as has been done in the Euphausids before Fraser (1936) showed the large individual differences in *Euphausia superba.*

Recapitulating all the Protozoeal stages, it can be said that the first is in the main comparable with the Calytopis stages of the Euphausids, while the second and third Protozoea corresponds more to the first Furcilia in Euphausids. This not taken too strictly, as in some points the Penaeus larva is even more primitive than the Euphausid larva. All the three Protozoea stages are more primitive compared with the larvae of the rest of the decapods.

*First Mysis.**	Length 3–3.5 mm. (average of 50 spm. 3.21 mm.) Figs. 61–67.
Carapace	Covering whole thorax dorsally and laterally. Rostrum keel shaped. Supra-orbital spine shorter and simple. Hepatic spine present. Ventro-anterior corner of carapace pointed. Posterior margin incurved. Length 1 mm. or more. (Fig. 61).
Abdomen	Segm. 1–5 of equal length, segm. 6 much elongated. Segm. 3–6 with dorsal spine, segm. 5–6 with lateral spine on each side, segm. 6 with 1 medio-ventral spine. (Fig. 61).
Telson	Movable towards abdomen, with med. incision, 1 lat. 7 terminal spines to each side.
A_1	3 protopod joints tipped with short branched embryonal flagella. 1 joint much elongated with dorsal fissure (developing statocyst); 2–3 joint with sensory hairs.
A_2	Much reduced in size. 2 jointed Protopod. Exopod 1 jointed flattened (coming antennal scale) Endopod usually 1 jointed (in one specimen examined 3 jointed as shown in fig. 61).
Labrum	A large semiglobular roof in front of mouth opening (fig. 61).
Labium	No change.
Md.	Further teeth have developed, long incisor teeth with lat. spines. Palp developing again, bud shaped (fig. 62).
Mx_1	Endites on coxa and basis further developed, especially basiendit. Exopod lost. Endopod 3 jointed delicate (fig. 63).
Mx_2	Endites and setae increased in number. "Exopod" with two lappets larger and with a row of ordinary setae. Endopod nearly unchanged (fig. 64).
Mxp_1	Changed towards mouth appendage (fig. 65).
Mxp_2	Natatory. Exopod 2 jointed, Endopod 5 jointed (fig. 66).

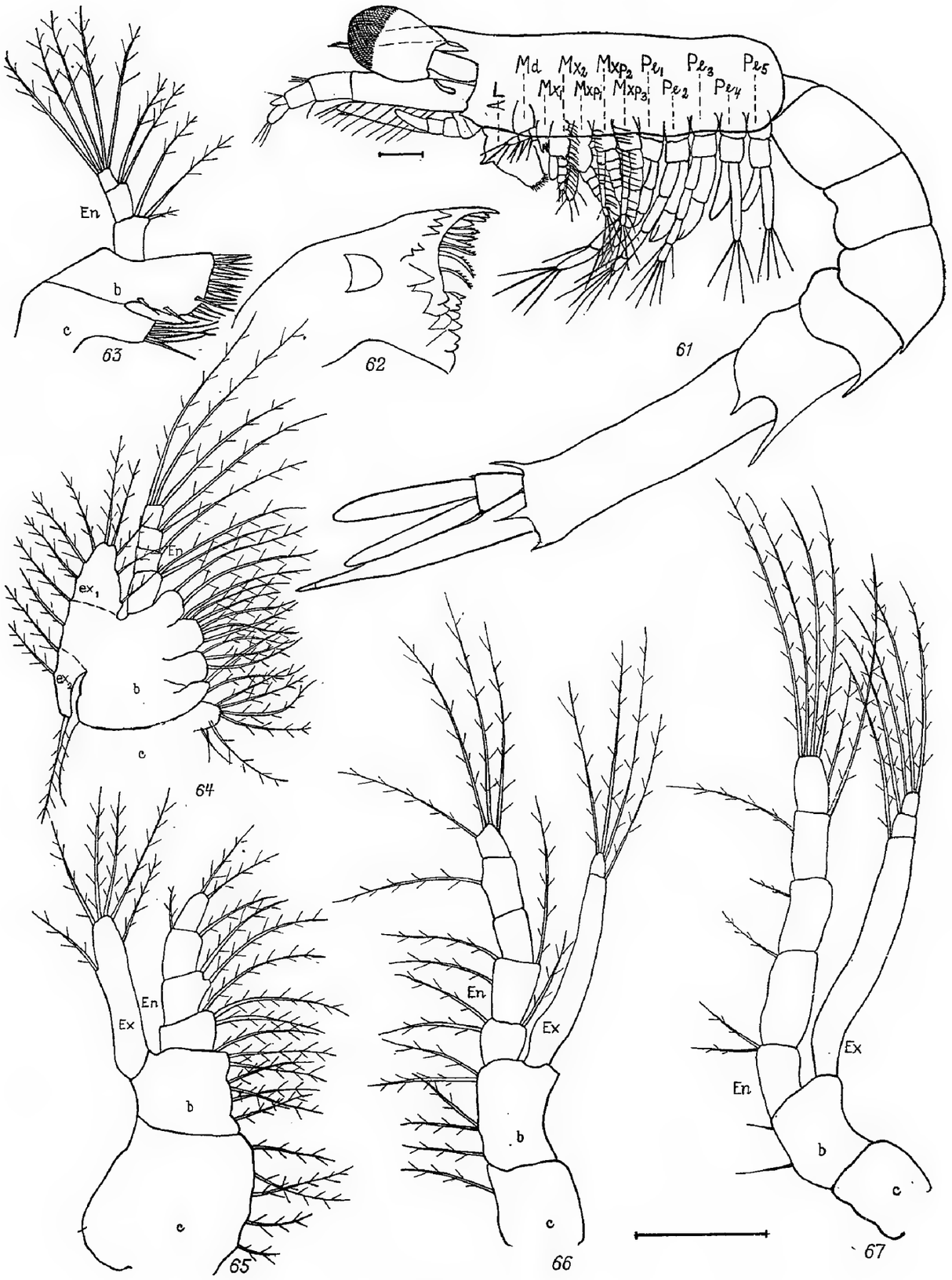

PLATE VII

First Mysis

Fig. 61 First Mysis.
Fig. 62 Mandible.
Figs. 63–64 First and second mandible.
Figs. 65–67 First to third maxillipede.

Mxp_3	Natatory. Exopod 3 jointed, Endopod 5 jointed (fig. 67).
Pereiopods	5 Pereiopods with 2 jointed protopod and rudimentary Exopod and Endopod. Enp. 1–3 with chela. (Fig. 61).
Pleopods	None or rudimentary buds, individual variation.
Uropod	Bifurcate.

**Editorial Note:* In six early mysis from Louisiana plankton deposited by Pearson in the U. S. National Museum, which are certainly *P. setiferus*, the rostrum and supraorbital spine are much longer than in Pearson's figure of Mysis I, and the rostrum is longer than in Heegaard's Mysis I (extending to the third segment of the antennular peduncle, or even beyond it).

Pearson (1939, p. 21) figures the exopods of the pereiopods as unjointed. In most specimens examined by me this was only the case with the last two exopods; the exopods on pereiopods 1–3 with chelate endopods were usually 3–4 jointed. Pearson's "about" 5 setae on the exopod, are 4 setae on unjointed and 6 setae on jointed Exopods (see fig. 61). Pearson also found bud-like pleopods although varying in size.

*Second Mysis.**	Length 3.4–4 mm. (average of 50 spm. 3.66 mm.). Figs. 68–87.
Carapace	Length 1.2–1.3 mm. Rostrum slightly decurved reaching nearly to tip of eyes. Supra-orbital spine shortened, hepatic spine more posterior, small lateral, marginal spine, ventro-anterior corner more pointed. Posterior indentation increased shaping lateral lobes of carapace. (Fig. 68, 72, 73).
Abdomen	6 segmented. Segn. 6 further elongated, segm. (4) 5–6 with dorsal spine. Spines on segm. 5–6 as in the first Mysis. (Figs. 68–70).
Telson	3 lat. spines, 5 post. spines to each side. Lat.–Post. spine largest. (Fig. 78).
A_1	Protopod 3 jointed with fully developed statocyst and stylocerite on 1 joint. Increasing number of sensory hairs on following joints. 2 flagellae still unjointed. (Fig. 74).
A_2	Protopod 2 jointed; Endopod 3 jointed; exopod unjointed shaping antennal scale. (Fig. 75).
Labrum Labium	Unchanged.
Md.	Corpus mandibulae growing, Incisor part starts a rotation in inward direction; all incisor teeth conical; molar teeth in rows; Palp 2 jointed. (Fig. 76).
Mx_1	Coxal endite reduced, suture between coxa and basis disappearing (fig. 77).
Mx_2	Still a suture between coxa and basis; Endopod 4 jointed; Exit 1–2 further developed and with increasing number of setae, but not on marginal part between Exites. (Fig. 79).
Mxp_1	More mouth appendage, shortened; coxa with gill. Exopod and Endopod vestigial with 3 and 4 joints (fig. 80).
Mxp_2	Changed towards mouth appendage; Endopod 5 jointed, Exopod 5 jointed swimming fan (fig. 81).
Mxp_3	Natatory. Exopod 5 jointed swimming fan, Endopod 5 jointed (fig. 82).
Pereipods	5 Pereiopods with 2 jointed Protopod, 6 jointed Exopod strong swimming fan, 5 jointed endopod. 1–2 Endopod chelate, 1–3 Exopod setae from 2 joint. 4–5 Endopod non chelate, 4–5 Exopod setae from 1 joint. (Figs. 83–87).
Pleopods	On first 5 abdominal segments, unbranched with 1 or 2 joints each being Protopod and Exopod because Endopod later develops from first joints. (Figs. 68–70).
Uropod	Unjointed Protopod, leaf shaped Exopod and Endopod. (Fig. 78).

**Editorial Note:* Heegaard's "Second Mysis" appears to represent a considerably less advanced stage than Pearson's, and it seems probable that there are more than two mysis molts in *P. setiferus* (*cf.* Heldt, 1938 and Hudinaga, 1942, on other species of *Penaeus*).

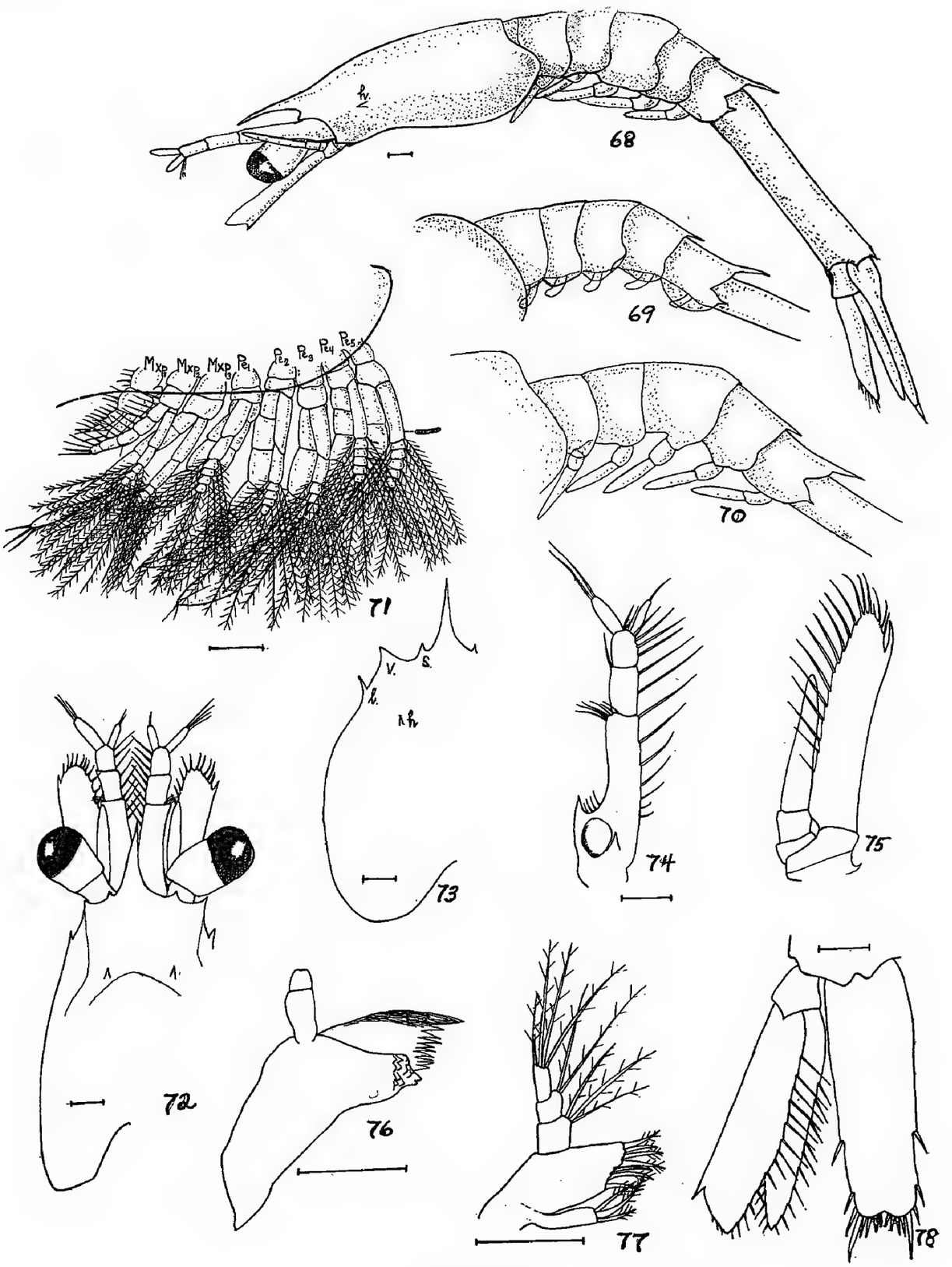

PLATE VIII

Second Mysis

Fig. 68 Second Mysis.
Figs. 69–70 Abdomen of two other specimens in second Mysis.
Fig. 71 Pereiopods.
Figs. 72–73 Carapace.
Fig.s 74 First antenna.
Fig. 75 Second antenna.
Fig. 76 Mandible.
Fig. 77 First maxilla.
Fig. 78 Telson and uropod.

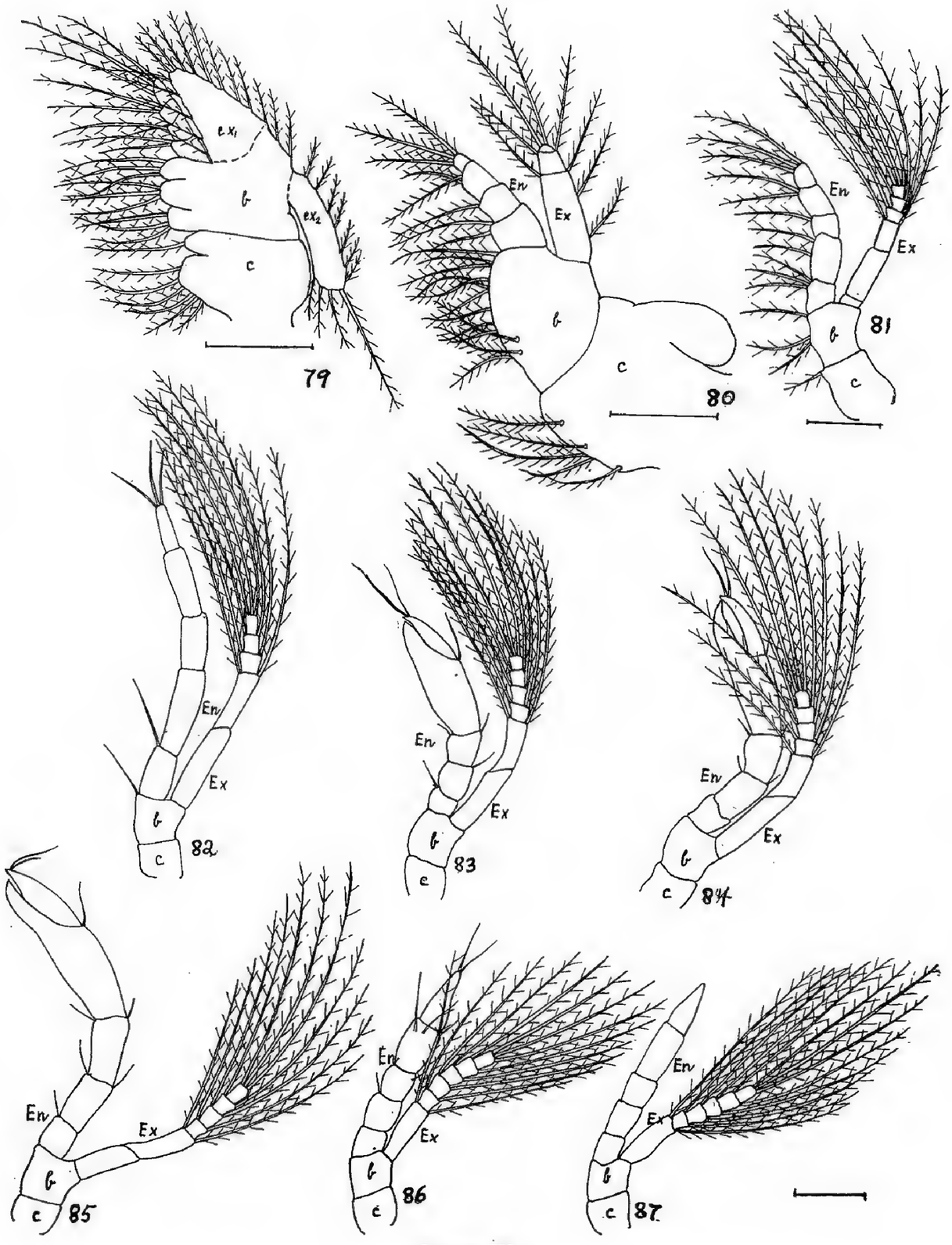

PLATE IX

Second Mysis

Fig. 79 Second maxilla.
Figs. 80–82 First to third maxillipedes.
Figs. 83–87 First to fifth pereiopods.

In Pearson's Louisiana material loaned by the U.S.N.M. (which is certainly *P. setiferus*), the most advanced mysis stages which could be found differed from Pearson's figure and description in having lost the posterodorsal spine of the third pleonic somite; and two out of three had lost the spine of the fourth somite as well. However, the pleopods were not setose, and the telson still extended well beyond the uropods. These specimens differed from Heegaard's figures and agreed with Pearson's figures in having a rostral tooth and in lacking the lateral spine of the fifth pleonic somite.

The posterodorsal spine of the fifth pleonic segment was shorter in all Louisiana mysis material examined than in any of Heegaard's figures of mysis stages.

It is conceivable that both Pearson's Atlantic mysis and Heegaard's Texas mysis may include other species of *Penaeus* than *P. setiferus*.

Pearson (1939, p. 23) describes the pleopods as follows: "Each Pleopod is uniramous (exopod only occurring), consists of three segments, and has a few short terminal setae." This judgment is based on 4 specimens. In my material I have first found the three-jointed exopod with setae in the following stage, the Post-mysis and further only in the first three pleopods, never in the two succeeding ones.

No earlier stage than second Mysis was taken in any quantity near the shores and the inlets or passes to the bay waters. But at the end of the second Mysis stage the larvae are standing in large quantities just outside the passes together with some older larvae. They were also taken in the pass itself, which was not the case with any younger stages. Weak specimens may be found nearly dying, floating at the surface or near it; but the specimens fully alive were not taken here. They were always found by me near the bottom, where they were taken in large quantities in some cases.

*Postmysis I:**	Length 4–5 mm. Figs. 88–105.
Carapace	Length 1.5 mm. Incl. rostrum, more shallow. Rostrum decurved, posteriorly going into Carina with 2 teeth. Supra-orbital spine still decreasing. Hepatic spine above labrum. Small lateral marginal spine disappeared. Fronto-lateral corner less pointed. (Fig. 88).
Thorax	8 segmented.
Abdomen	6 segmented. Vestigial dorsal spine on segm. 4–5 and sometimes a very small on seg. 3; lateral spine on segm. 5 disappeared, 1 stiff seta on lat. pleura of segm. 5. Segm. 6 unchanged. (Fig. 88).
Telson	Cleft more shallow. (Fig. 105).
A_1	Peduncle 3 jointed. First joint with statocyst, stylocerit and long lateral spine, plumose setae from this spine to 3 joint, which is smooth. Both flagellae 3 jointed. (Fig. 89).
A_2	More elongated, Protopod 2 jointed, long exopodial antennal scale; Endopod 3 jointed with long distal joint tipped with long seta (fig. 90).
Labrum	More flattened, comparatively smaller, frontal spine more like a cone (fig. 88).
Labium	Unchanged.
Md.	Corpus mandibulae more stout, pars incisiva and pars molaris less dominant. Pars molaris drawn a little back and decreased from incisor part. Palp 2 jointed and setose (fig. 91).
Mx_1	Reduced, more curved Endites pointing more posteriorly; ligature between coxa and basis totally lost. Endopod vestigial, 2 jointed non setose. (Fig. 92).
Mx_2	Suture between coxa and basis disappearing, Endites reduced; Endopod unjointed, non setose, vestigial. Exopod or exit 1–2 further developing, with shorter marginal setae. (Fig. 93).
Mxp_1	Reduced; still distinct coxa and basis; Exopod 3 jointed, Endopod 4 jointed both vestigial an dnearly non-setose. Gill on coxa (fig. 94).
Mxp_2	Protopod 2 jointed with gill on coxa, vestigial Exopod as bud on basis; Endopod gill on coxa; mouth appendage. (Fig. 95).

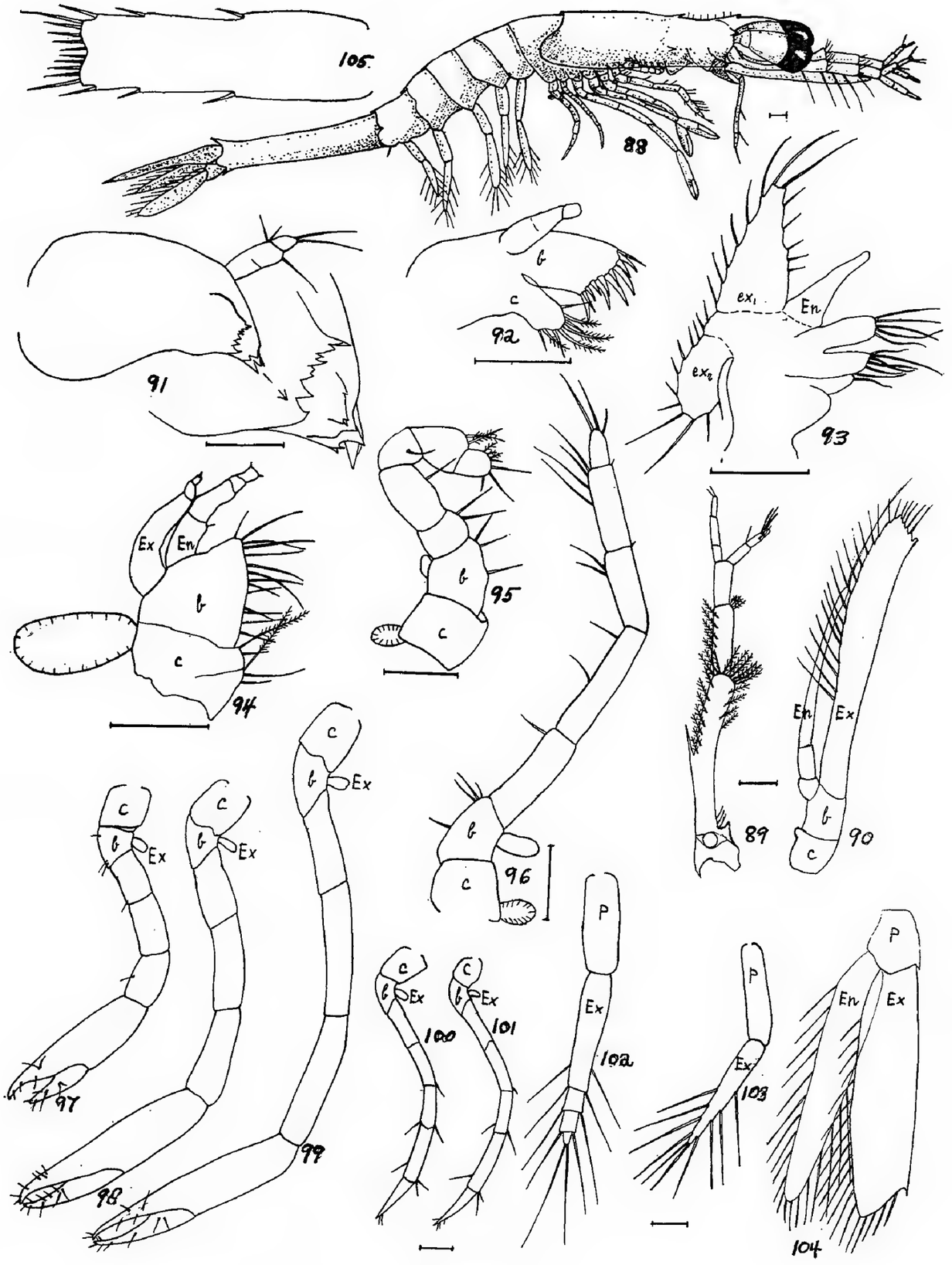

PLATE X

Postmysis

Fig.	88	First Postmysis.
Figs.	89–90	First and second antenna.
Fig.	91	Mandible.
Figs.	92–93	First and second maxilla.
Figs.	94–96	First to third maxillipedes.
Figs.	97–101	First to fifth pereiopods.
Figs.	102–103	First and fifth pleopod.
Fig.	104	Uropod.
Fig.	105	Telson.

Mxp_3	Protopod 2 jointed with gill on coxa, vestigal Exopod as bud on basis; Endopod 5 jointed. (Fig. 96).
Pereiopods	5 pairs, 2 jointed Protopod, vestigial unjointed Exopod, 5 jointed Endopod, three first with chelae (figs. 97–101).
Pleopods	5 pairs with unjointed Protopod; first 2 or 3 with jointed Exopod following unjointed Exopod, all setose. (Figs. 102–103).
Uropod	More setae developed. (Fig. 104).

**Editorial Note:* The rostrum in both Heegaard's and Pearson's figures of this stage is longer than in six specimens (certainly *P. setiferus*) from Pearson's Louisiana material, where it extends no farther than to the basal one-fifth to one-third of the eyeball. [Although the distal part of the rostrum is obscured in the reproduction of Heegaard's Figure 88, the original shows the tip of the beak reaching to the distal half of the eyeball.]

Heegaard's figure represents an unusual combination of features, in having two dorsal teeth on carapace and rostrum although a small spine still persists on the fourth pleonic tergite.

The limbs have changed considerably in this stage. The natatory exopods from the five pairs of pereiopods have disappeared or nearly disappeared. The first three pairs of pereiopods are with functioning chelae, the third pair being the longest and extending forward nearly to the front of the eye. The last two pairs of pereiopods are more weakly developed than the rest. The absence of exopods changes the method of locomotion of the larva. Forward swimming is now produced by the movement of the pleopods.

*Postmysis II:**	Length 6–7 mm. Figs. 106–122,
Carapace	Length 2 mm. or more. Rostrum a little shorter, slightly curved upward. Carina with 3 teeth. Supra-orbital spine present, but reduced and withdrawn, lost in few specimens. Hepatic spine unchanged. Fronto-lateral corner rounded. Cephalothoracal groove developed (fig. 106).
Thorax	8 segmented.
Abdomen	6 segmented. 4–5 segm. with pleural plates, 4 stiff setae on margin of pleural plate of 5 segm. Segm. 5–6 with minute dorsal spine. Segm. 6 with ventral spine (fig. 106).
Telson	Posterior convex, laterally setae posterior to second lateral spine. (Fig. 122).
A_1	Setae on peduncle increased, flagellae with 3 and 4 joints. (Fig. 108).
A_2	Antennal scale larger with tooth and more setose; Endopod, setae developed along med. margin of 3 joint. (Fig. 108).
Labrum	more setae. (Fig. 109).
Labium	Lobes more rounded, fissure between lobes narrower. (Fig. 110).
Md.	Pars molaris further reduced compared with incisor part. Palp 2 jointed with more setae. (Fig. 109).
Mx_1	2 Endites with strong cutting teeth, especially on basiendite, Endopod small unsegmented lobe with single spine, no Exopod as in Mysis stage. (Fig. 110).
Mx_2	No suture between coxa and basis, and none in Exopod, $Exit_{1-2}$ and Protopod has coalesced to a plate with many short marginal setae. Endites reduced with few setae. Endopod vestigial and unjointed (fig. 111).
Mxp_1	Shorter but wider. Suture between coxa and basis lost. Lobus externa strongly developed. Endopod and Exopod unjointed, vestigial Endopod with 2 characteristic medial setae; Exopod tipped with short seta; gill from coxa large. (Fig. 112).
Mxp_2	Nearly unchanged but Exopod lost. (Fig. 113).
Mxp_3	Nearly unchanged, but without Exopod. (Fig. 114).
Pereiopods	Without Exopod (figs. 115–119).
Pleopods	1–3 with jointed Exopod; 4–5 with unjointed Exopod but with stiff posterior pointing setae on Protopod. (Figs. 106, 120, 121.)
Uropod	Unchanged.

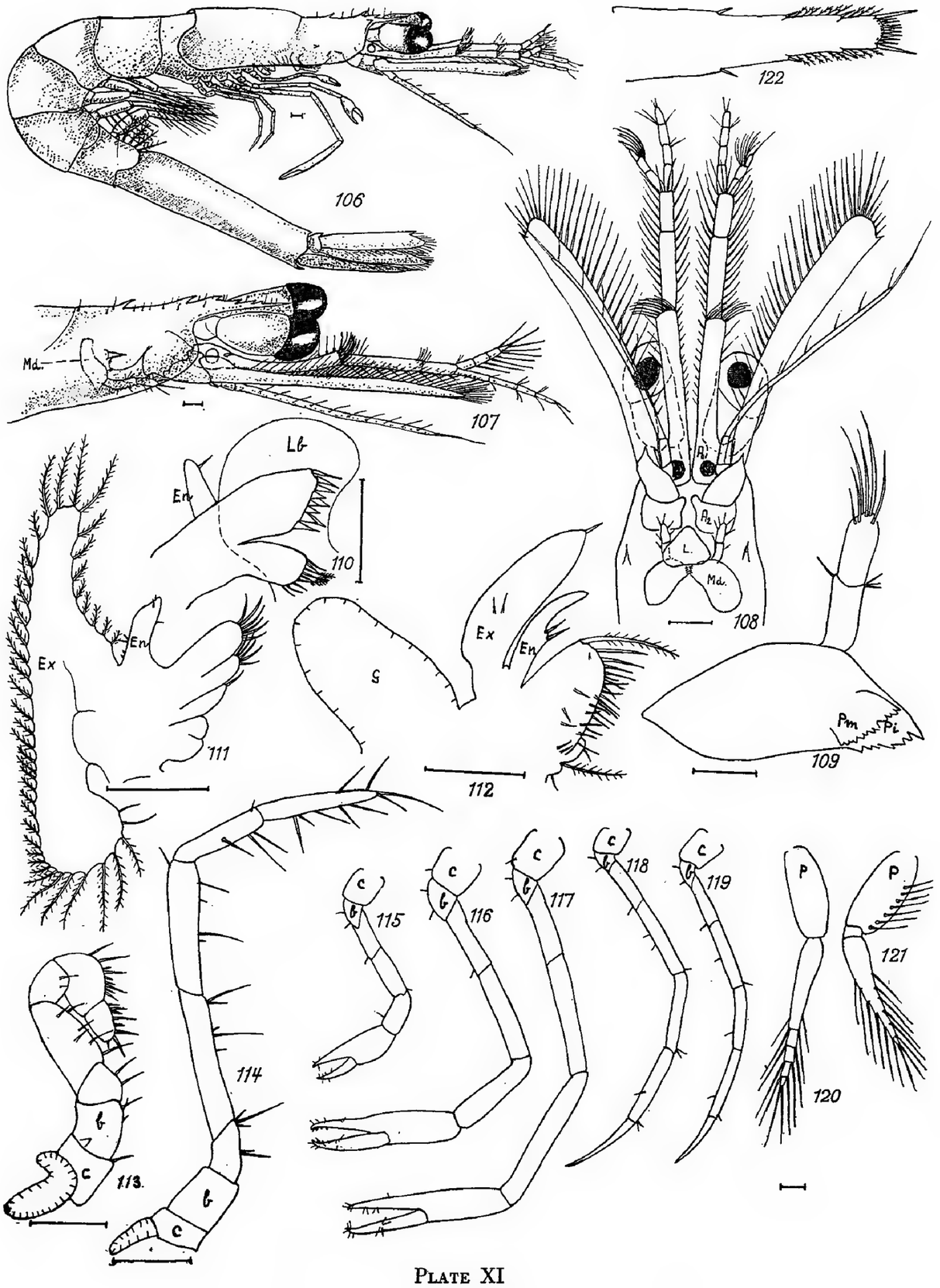

Plate XI

Postmysis

Fig. 106 Second Postmysis stage.
Fig. 107 Fifth(?) Postmysis stage.
Figs. 108–122 Second Postmysis stage.
Fig. 108 Cephalon from ventral.
Fig. 109 Mandible.
Fig. 110 First maxilla and part of labium.
Fig. 111 Second maxilla.
Figs. 112–114 First to third maxillipedes.
Figs. 115–119 First to fifth pereiopods.
Figs. 120–121 First and second pleopod.
Fig. 122 Telson.

**Editorial Note:* Of fifteen Louisiana specimens certainly of *P. setiferus* which, like Heegaard's "Postmysis II," had lost the posterodorsal spine of the fourth pleonic segment but had one on the fifth as well as the sixth, 8 had one rostral tooth, 5 had two teeth (including the epigastric), and 2 had three teeth like Heegaard's figure. Of twenty-four Louisiana specimens which, like Pearson's figure, lacked pleonic tergal spines in advance of the sixth segment, 2 had one rostral tooth, six had two teeth (like Pearson's), and 16 had three teeth (the third tooth being a minute rudiment in 6). Both Pearson's and Heegaard's figured specimens thus seem to be of the less common types. In addition, Heegaard's 6–7 mm. length is considerably greater than in the above-mentioned Louisiana material (all less than 5 mm.); and also greater than in Pearson's second postmysis both of *P. setiferus* (4.5–6.0 mm.) and of *P. aztecus* (5.2–5.4 mm.).

Reliable distinction of the swimming postmysis stages of the three common Atlantic North American species of *Penaeus*, and of the postlarvae and juveniles of the two grooved species, is a difficult problem, although some progress is being made. Larvae of the grooved species younger than postmysis have not yet been described, unless some of Pearson's Atlantic Coast "*P. setiferus*" belong to *P. duorarum* (which seems to have a bathymetric range little deeper than that of *P. setiferus*).

The increase of the larvae from 4–5 mm. to 6–7 mm. seems a very fast growth as only a relatively few days would be expected between these two moults. Of these larvae I have only about twenty specimens, as they first occurred shortly before I left and at a time when the major stock of larvae still was in the Mysis stages and some even younger. I am therefore not absolutely certain about their identity. From Pearson's (1939) descriptions it should be *Penaeus setiferus*, but two other species of *Penaeus* occur in the area, and one of them, *P. aztecus*, is very abundant in deeper water just outside the investigated locality. As the size change is rather remarkable, it may be the larva of this grooved shrimp which has started to emigrate towards the shores and inlets. The older *P. aztecus* postmysis stages should according to Pearson be a little larger than *P. setiferus*, although his second postmysis is of similar size.

The larva has a distinct groove dividing the cephalic part of the thoracal part. This groove, which can be recognized as early as the second Mysis (Fig. 72), starts dorsally in line with the mandibles, and in contrast to the cervical or branchial groove in some Reptantia, in which the groove goes from the middle dorsal point in a lateral-anterior direction to both sides down the carapace, this groove goes from the dorsal point in a lateral-posterior direction down the sides of the carapace.

The next stage in my collections (fig. 107) is still of the Sicyonine type (Burkenroad, 1934a, p. 15; 1934b, pp. 135–7; 1939, p. 45–53; 1945), which means without exopods on the pereiopods as well as several other features like those of adult *Sicyonia*. Of this stage I have only a single specimen. The carina and rostrum has developed a further number of teeth, with a total of six teeth, the three posterior ones are the old ones from the previous stage, but in addition to that three teeth have developed on the dorsal margin of the rostrum. The ventral side of the rostrum is still without teeth, as also the fronto-lateral margin of the carapace has been still more rounded and withdrawn from the second antenna and the mandibular palp. On the second antenna especially on the proximal joint some more sensory hairs with two little sensory bulbs at the base of each hair have developed. Otherwise, there is no major change except that everything has grown some larger.

From then on I do not have any older larvae, but as shown by Burkenroad, Heldt and Hudinaga, at a certain stage of the larval life the exopods develop again on the

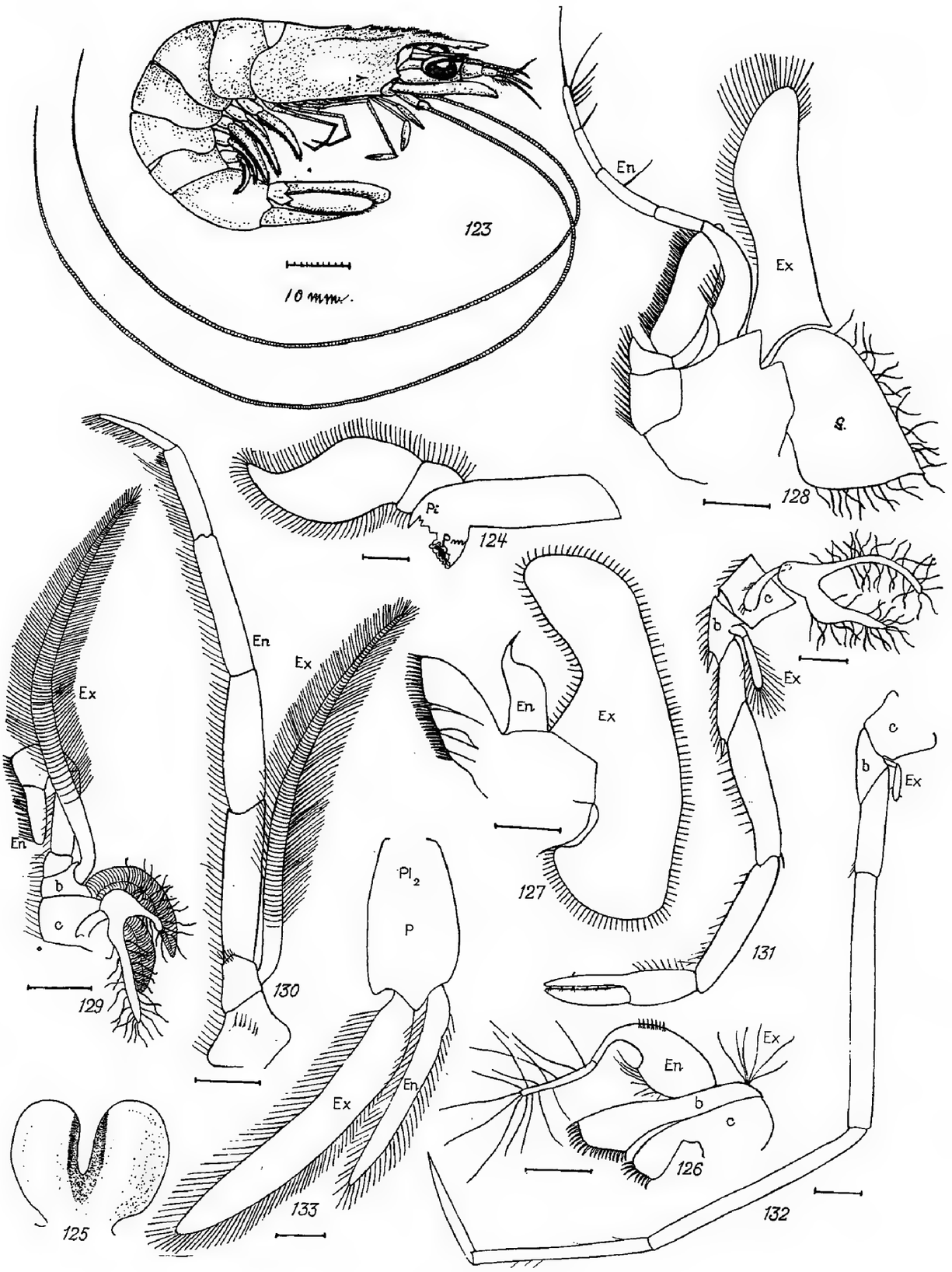

PLATE XII

Adolescent

Fig. 123 From lateral.
Fig. 124 Mandible.
Fig. 125 Labium.
Figs. 126–127 First and second maxilla.
Figs. 128–130 First to third maxillipedes.
Figs. 131–132 First and fifth pereiopod.
Fig. 133 Second pleopod.

maxillipedes as well as on the pereiopods, and also an endopod develops on the pleopods. From here on the young shrimp is much like the adult, only not fully grown and not yet mature, and it may properly be called Post-larval.

Adolescent.	Figs. 123–133.
Carapace	With toothed Rostrum, hepatic spine and pointed fronto-lateral corner (fig. 123).
Telson	Laterally setose, posteriorly pointed.
A_1	3 jointed tipped with 2 shorter flagellae.
A_2	Protopod 2 jointed, exopodial antennal scale; Endopod 2 basal joint and long flagella (fig. 123).
Labrum	As in Sicyonine stage.
Labium	Fissure between lobes narrow. (Fig. 125).
Md.	Corpus mandibulae broadly oval and concave with flat incisor process and thick molar process. Palp flattened 2 jointed setal hairs in margin. (Fig. 124).
Mx_1	Coxa and basis separate, each with slim endite; Endopod 2 jointed; Exopod a knob with long hairy setae (fig. 126).
Mx_2	4 endites on Protopod with row of short spines; Endopod vestigial; Exopod large leaf without divisions. (Fig. 127).
Mxp_1	Coalesced Protopod with free gnathal lobes. Endopod 5 jointed flagellum. Exopod leaf shaped; gill blade on protopod. (Fig. 128).
Mxp_2	2 jointed Protopod; S shaped, 4 jointed Endopod; flagelliform Exopod (fig. 129).
Mxp_3	2 jointed Protopod; 5 jointed Endopod, 3 first chelate; Exopod vestigial, 2 130).
Pereiopods	2 jointed Protopod; 5 jointed Endopod, 3 first chelate; Exopod vestigal, 2 jointed. (Fig. 131–132).
Pleopods	Unjointed Protopod, large Exopod, smaller Endopod. (Fig. 133).

SUMMARY

An investigation was made of the spawning and larval history of *Penaeus setiferus* in the Gulf of Mexico off Aransas Pass, Texas.

In 1948 ripe *Penaeus setiferus* was present in the open Gulf from the middle of May to the middle of June when the adults disappeared. The eggs are believed to have been spawned about six miles offshore in 20–25 m. of water, where the ripe adults were concentrated.

Larvae were caught in large quantities in the same places where the ripe adults were found, and in the beginning only in these localities. Two eggs believed to be *P. setiferus* were taken with some sand from the bottom in this locality, and many females caught were so ripe that they threw their eggs on the way back to the laboratory.

Viable eggs could not be obtained in captivity nor at sea, nor planktonic larvae reared in the laboratory except for a few going through single ecdyses, so the larval stages described are those collected in the plankton net.

It is pointed out that small variations in characters, which in the Nauplius and especially in the Mysis and the Postlarval stages might be taken as division marks between two stages, also can be found in the Protozoea phase of the larval life, but here they are not noticed because much more distinct characters divide the Protozoea

phase of the larval life in three stages. Some authors may thus have been misled as to the number of stages in parts of the larval life.

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An Introduction to the Zoogeography of the Northwestern Gulf of Mexico with Reference to the Invertebrate Fauna

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ABSTRACT

The estuarine and neritic waters of the northern Gulf of Mexico, especially along the coasts of Texas and Louisiana, are characterized by broad ranges of environmental factors, providing conditions favorable to temperate organisms in winter and tropical organisms in summer. The fauna is a mixture of temperate Atlantic and tropical Caribbean elements, with a very low endemic component. The distribution of many of the Atlantic species occurring in the northern Gulf is characteristically disjunct, they being absent from southern Florida or represented there by stunted individuals or reduced populations. Many of these species were apparently continuous in distribution across northern Florida during high stands of the sea in late interglacial periods of the Pleistocene.

The small number of endemic species—about 10% in most invertebrate groups—may be a reflection of the environmental extremes which enable the development of large populations of wide-ranging adaptable species at the expense of the development of indigenous forms. Similar conditions apparently prevailed well back into the Tertiary, and the evidence of the Cretaceous suggests that the region now bounded by the Gulf Coastal Plain has been in an area of transition between northern and southern environments since that time.

The pronounced range of environmental factors has many effects on the communities of the region, and fluctuations in populations are pronounced. Populations in bay waters in particular undergo wide variations as a result of killing cold, high salinities during droughts, and excess drainage of fresh water during floods. Both droughts and killing cold spells may be increasing in frequency, especially in south Texas.

These waters are nevertheless productive. Extensive oyster reefs occur in the bays, and the shallow bottom of the neritic Gulf is inhabited by large colonies of sea pansies and sea whips, sand-loving echinoderms and various bivalves. One of the largest invertebrate populations is that of the various species of penaeid shrimp. This population is one of the key—if not the key—components in a complex major ecosystem which includes the marine and estuarine environments.

I.

History of the Northern Gulf of Mexico and Its Fauna

1. Description of the Gulf of Mexico

The Gulf of Mexico is an oval or kidney-shaped sea, connected with the Caribbean by the Yucatan Passage, slightly more than 100 miles wide and some 1,000 fathoms deep, and with the Atlantic Ocean by the Straits of Florida, which is not quite as wide as the Yucatan Passage and less than 300 fathoms deep north of Cay Sal Bank. From Cape Sable westward across the Gulf to Mexico the distance is 1,000 miles. Between the Delta of the Mississippi and the northern coast of Yucatan, the Gulf is roughly 500 miles wide. Farther west, on a line between Cameron Parish, Louisiana, and the coast of Tabasco, the Gulf of Mexico is 250 miles wider. The shore line of the Gulf, from Cape Sable to Yucatan, is roughly 5,000 miles long, not counting the shores of bays and islands. The total tidal shore line is more than

17,000 miles in the United States alone, according to figures compiled by the U. S. Coast and Geodetic Survey. The Gulf coast of Texas, islands and all, is about as long as the coast of California (Table 1), and the Louisiana coast is more than twice as long.

Structurally, the Gulf of Mexico does not begin at the shore line, but with the broad, gently sloping Gulf Coastal Plain, the northward limit of which is roughly the base of the exposed Cretaceous beds. This Gulf Coastal Plain is continuous with the South Atlantic Coastal Plain. The Gulf Coastal Plain is indented by two great embayments, the Mississippi embayment, extending as far north as Cairo,

TABLE 1

Comparative shore lines, U. S. Gulf Coast and California

	U. S. Geol. Survey*			U. S. C. & G. S.†
	Mainland	Islands	Total	Total
Florida	1,273	1,257	2,530	5,391
Alabama	174	117	291	607
Mississippi	99	103	202	359
Louisiana	1,222	591	1,713	7,721
Texas	973	709	1,682	3,359
Total, Gulf Coast	3,641	2,777	6,418	17,437
California	1,264	291	1,555	3,427

* From Information Please Almanac
† From World Almanac

Illinois, and the Rio Grande embayment, and two smaller embayments. This plain, which slopes about 5 feet per mile, extends beneath the water at a gradient of 8–12 feet per mile to form a broad continental shelf. The shelf is 175 miles wide west of Florida, and 140 miles wide south of Louisiana. The Gulf Coastal Plain and the continental shelf are formed of Cretaceous, Tertiary, and Quaternary sediments. The Tertiary sediments attain tremendous thickness near the present coast line. It has been estimated that the thickness at Grand Isle, Louisiana, is 30,000 feet. The sediments are much deeper than the deepest part of the Gulf, the Sigsbee Deep, which is some 13,200 feet deep. The information on the sedimentary volumes in the Gulf Coastal Plain has been summarized by Murray *et al.* (1952). At the edge of the continental shelf, in about 70 fathoms, the slope drops off at a gradient of 400–600 feet per mile into the elongate basin of the Sigsbee Deep.

The continental slope is much steeper west of Florida and northwest of Yucatan, and less precipitous along the east coast of Mexico. Some details of the slope off the Florida panhandle were described by Jordan (1951). An interesting feature of the shelf south of Louisiana is the small submarine canyon, marking the Pleistocene outlet of the Mississippi River. The shoreward portion of this canyon has been filled with sediment, but it can be traced underground to the vicinity of Houma (Figure 1). A similar canyon is found in the shelf south of the Apalachicola River. On the continental shelf west of the Mississippi there are many hillock-like structures, domes, or plugs, along the 100 fathom line, rising to within 10 to 30 fathoms of the surface, and usually supporting small coral reefs. Surveys by Mattison (1948) show many interesting minor features much nearer to shore along the Texas coast, including a shallow valley with small coral heads at 26° 48′ N, and finger-

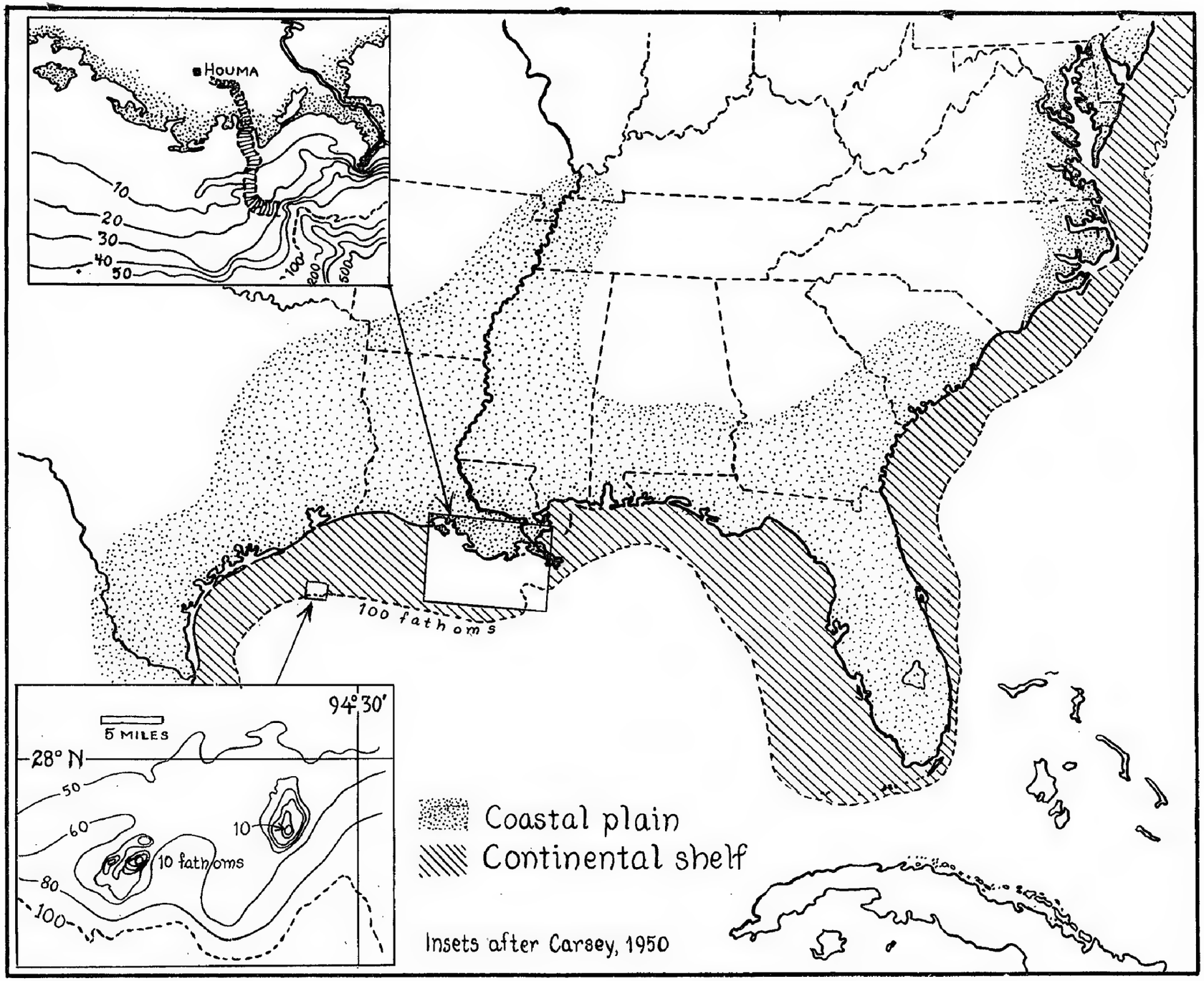

FIGURE 1

General map of the southeastern United States, showing extent of coastal plain and continental shelf, with insets showing submarine canyon off Louisiana and dome-like structures near the 100 fathom line. After Carsey, 1950.

like submarine topography within a mile of the shore of Padre Island in the general vicinity of the shell concentrations along the beach (Figure 2).

The underlying structure is complex and varied, with many local irregularities, especially in the Mississippi Embayment. The Cenozoic sediments along the present coast form a thick wedge, thought by many Gulf coast geologists to lie in a deep basin, the so-called "Gulf-Coast Geosyncline." There has been a gradual gulfward advance of the central Gulf coast throughout the Cenozoic with an alternation of marine and deltaic cycles of sedimentation (Murray, 1947). Salt domes protrude through the sedimentary strata, originating below the Cretaceous basement, perhaps in the Permian. There are veritable pillars of salt several miles in height, "driven like nails in a plank" (Stephenson, 1928). Of Avery Island, Louisiana, a salt plug which has broken through the surface, Carsey (1950) says: "The reader will get a more impressive picture of this salt plug if he will imagine himself standing on this circular island which is less than 3 miles wide, but whose core is a column of salt extending downward to a mother stratum 5, 6, or 7 miles deep. This mass is favorably comparable in height, though not in size, with the greatest mountains of the earth." These salt formations are associated with many occurrences of oil in this region.

2. The Cretaceous

The fossil record of the upper and middle Cretaceous along the northern edge of the Gulf Coastal Plain is a rich one, and from it some idea of the conditions in the seas toward the close of the Mesozoic can be inferred. It must be borne in mind that a very long span of time is represented in this record, and that tentative generalizations are subject to error.

The fossil assemblages are especially rich in such reef- or biostrome-building pelecypods as rudistids and ostreids. Corals and crustaceans are also well represented, and the ammonites, of course, are abundant. Since the living representatives of most of these groups inhabit shallow tropical seas, such conditions have been postulated for the Cretaceous of this region. The rudistid biostromes of the Edwards formation (Lower Cretaceous) were apparently formed in shallow epicontinental seas, with warm, clear water of normal salinity, according to Matthews (1951). The occurrence of ostreids suggests, but does not prove, local estuarine conditions, perhaps with somewhat lower temperatures or a greater temperature range, and more probably with a wider salinity range, than those that prevailed in the environment of the rudistids and many of the decapod Crustacea.

It has been suggested by Schuchert (1935) that there were also salt-producing lagoons along the Cretaceous shore, from which the salt of the present domes may be derived. Most geologists, according to Carsey (1950), suggest a Permian or older age for the salt of these domes, and, as he says, "The origin of salt domes is, of course, a highly controversial subject." If the conditions encountered in the present Laguna Madre are any criterion, it is difficult to see how salt forming lagoons could have existed contemporaneously with the violent rains attributed to Cretaceous climates by the paleo-climatologists. Although there is today in the region of the Laguna Madre a great excess of evaporation over precipitation, and heavy downfalls in excess of six inches over a 24-hour period are infrequent, these downpours, together with the damped tidal exchange, have so far prevented any con-

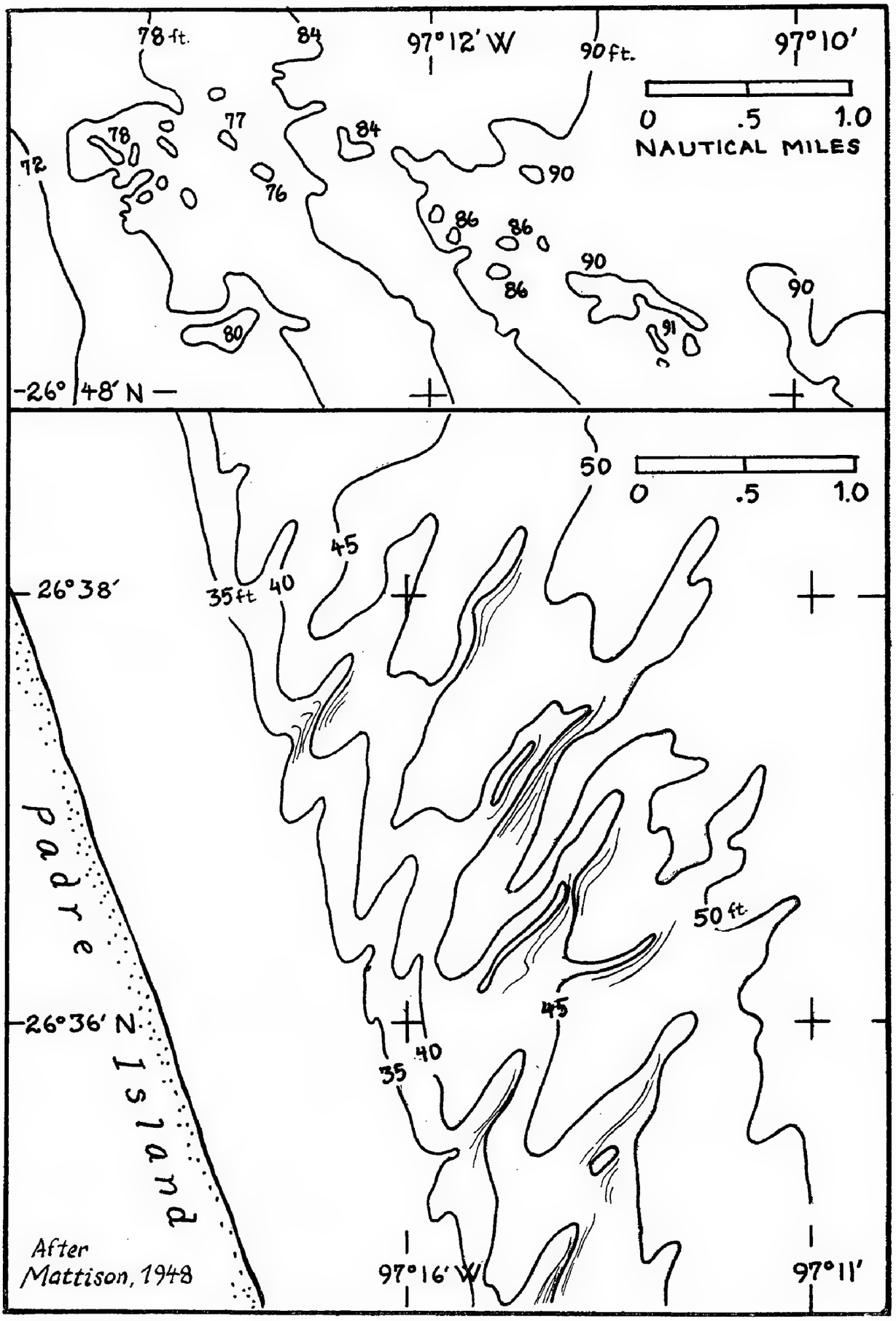

FIGURE 2

Details of minor topographic features near the Texas coast. After Mattison, 1948.

spicuous deposition of salt in the region. There are a few salt beds, but these are negligible as compared with the salt deposits of the domes.

Ammonites are rarely found associated with fossil reefs, as Scott (1940) has pointed out, and evidently, according to this writer at least, their occurrence in association with rudistids and oysters in assemblages is accidental. This observation is reinforced by Matthews (1951), who states that "cephalopods are not known in the Edwards biostromes, and this bears out the interpretation that cephalopods have never been reef dwellers." It may be that conditions leading to the fossilization of ammonite shells were less favorable on the reefs, where waves would tumble the shells against the hard reef or roll them into nearby soft bottom areas. In this connection it is of interest to note the investigation by Menard and Boucot (1951) of the movement of brachiopod shells over sand. It was found that currents too weak to move the individual sand grains were effective in moving the larger objects across the sand.

Whatever the ammonites ate, and modern cephalopods as a whole are predaceous animals, it would seem that reefs would be good hunting grounds. The meager information available on the food habits of *Nautilus* indicate that this cephalopod is at least in part a scavenger as well as a carnivore, preying upon crustaceans. Perhaps, like modern cuttlefish and octopuses, the ammonites lay in wait for passing prey and caught it with their tentacles; *Nautilus* probably feeds in a similar manner. One of the great mysteries of the past is the disappearance of the ammonites at the close of the Cretaceous. Perhaps it is a mystery that will never be solved; all we know is that they died out.[1] Spath (1933) has very cautiously suggested that some of the octopuses may be the lineal descendants of those ammonites with reduced shells *(Baculites)*. Since nothing is known of the soft anatomy of an ammonoid, such suggestions are little more than speculations, but it does not seem necessary to follow Berry (1928) in denying them altogether.

One cannot, in the light of present knowledge of the distribution of cephalopods on the Gulf Coast, postulate a stenohaline habit for Cretaceous ammonites as confidently as did Scott (1940): "The modern Cephalopods are exclusively marine animals. No authentic record exists of their habitual occupation of either fresh or brackish waters. They are occasionally carried by storms or currents into estuaries but cannot tolerate even slightly reduced salinity. There is every good reason to believe that such has always been the case with cephalopods." Gunter (1950b), however, has presented data indicating that the squid *Lolliguncula brevis* is capable of tolerating a fairly broad salinity range at some times. He found this squid in salinities from 17.7 to 37.2 o/oo, and also reports *(in litt.)* that *Octopus vulgaris* is occasionally caught in the Texas

[1] The problem of "the great dying" has taxed the ingenuity of many paleontologists. An explanation is here suggested: Recent geophysical evidence suggests that there may have been a large increase in the volume of the ocean toward the close of the Cretaceous as a result of volcanic action and the intrusion of "new water" from the magma. Although it is now generally held that the composition of the ocean has been comparatively constant, such an influx of water would be high in CO_2 and would be expected to upset for a time the CO_2 equilibrium between atmosphere and ocean. This is suggested by the increase in carbonate precipitation indicated by the Globigerina ooze. Now it is well known that the respiratory hemocyanin of modern cephalopods, especially squid, is more highly susceptible to increased CO_2 content than that of gastropods, Crustacea and Limulus, and for this reason squids do not survive long in aquaria. Also, hemocyanins in general have a higher affinity for CO_2 than sea water itself (Redfield *et al.*, 1926). It is possible that at the close of the Cretaceous there were temporary CO_2 excesses which selected out the highly organized and possibly unadaptable ammonites by acting on their most vulnerable physiological adjustment, and resulted in their departure from the scene, while at the same time such excesses had no effect on most other invertebrates in the sea.

bays. If the ammonites required higher salinities than those tolerated by some reef organisms, we might expect that they occurred seasonally or sporadically during periods of lower rainfall, invading brackish areas during high salinity intervals. There is also an indication that cephalopods can tolerate hypersalinities; Robson (1927) has discussed the occurrence of several species in the Suez canal in salinities up to 50 o/oo.

Scott endeavored, on the basis of his knowledge of ammonites, to reconstruct the approximate character of the Cretaceous seas of Mid-Albian time and to correlate types of ammonites with the different types of shallow sea. His speculations are predicated upon the ideas that ammonites were exclusively marine and did not frequent reefs. Neither of these conceptions of ammonoid ecological limitation may be universally true, but his paper, with its bathymetric classification of Cretaceous seas, provides an interesting introduction to the study of the rich ammonite fauna of the Gulf Cretaceous. His views are best summarized by combining several of his figures in a single diagram (Figure 3).

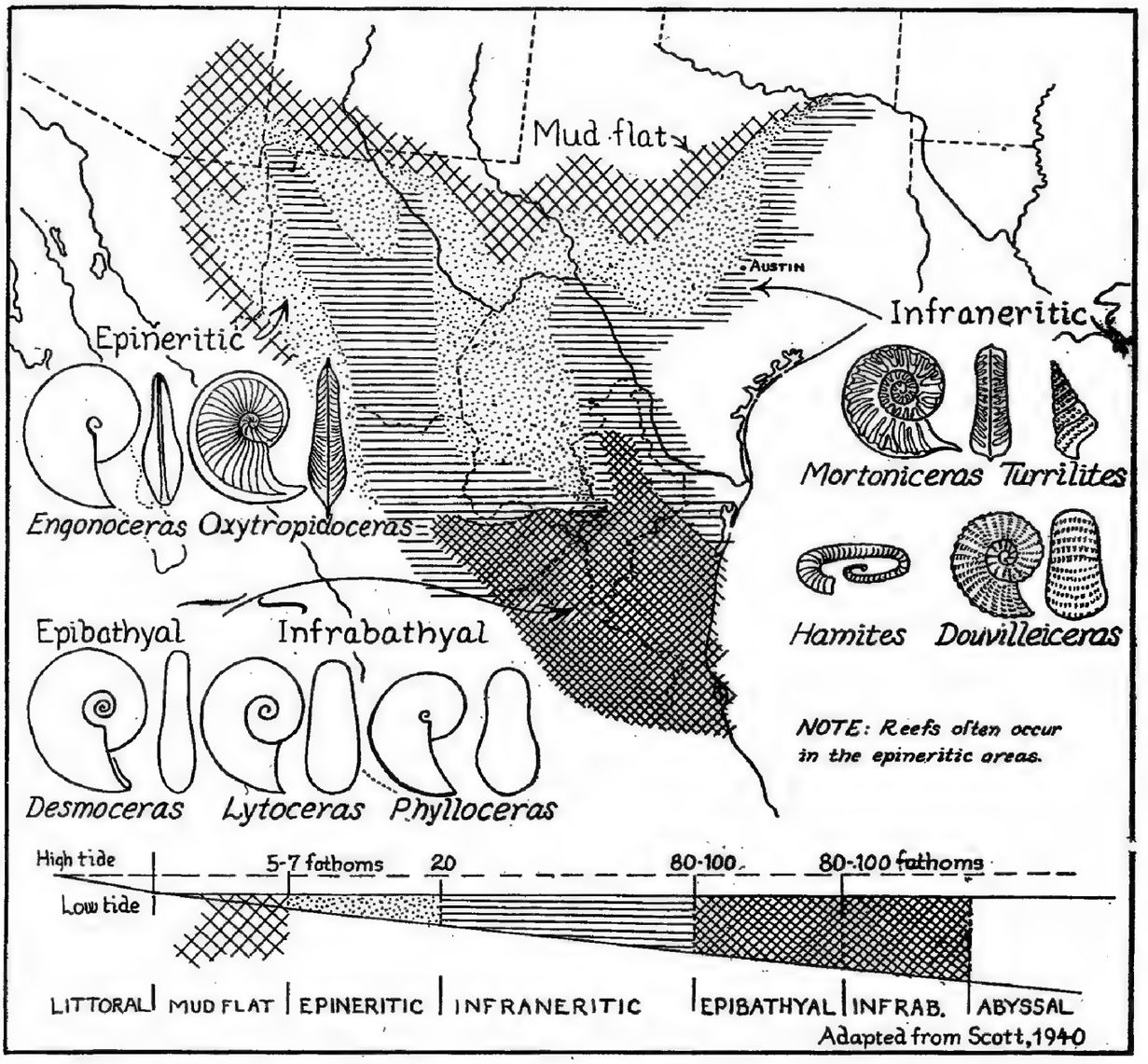

FIGURE 3

Ecological distribution of ammonites and reconstruction of the seas of Mid-Albian (Cretaceous) time of Texas and northern Mexico. Adapted from Scott, 1940, figures 8 and 9.

Since the ammonites did not survive the close of the Cretaceous— "the time of the great dying," in Walther's picturesque phrase—it is more instructive to turn to organisms represented by identifiable descendants in modern seas. The Crustacea, to judge from Stenzel's work (1935, 1944, 1945), are members of families—and in many cases, genera—occurring today in Gulf waters. There were several species of palinurids, the "spiny lobsters" which are an important element in the commercial fishery of Florida and the West Indies, two of them representatives of the genus *Linuparis*. This genus is now reduced to a single species, *L. trigonis*, in Japanese waters. The related homarids were apparently much better represented in the Cretaceous than they are today. Stenzel finds three species of *Homarus*, now principally a boreal-arctic genus (with a Mediterranean relict), whereas this family is represented today in the West Indies by only a few offshore or deep water species. The frog crabs (Raninidae) and the dromiids occur both in the Cretaceous and the present, and the calappids seem to have been more abundant, at least in number of species, than they are today. Living calappids are characteristic members of present day assemblages; two species are common along the northern Gulf Coast. Three living genera to which Cretaceous fossils have been assigned by Stenzel are *Galathea*, a widespread genus represented in the American tropics by its relatives *Munida* and *Munidopsis*, offshore and deep-water forms, the burrowing shrimp *Upogebia*, whose present day representative occurs on mud flats from Woods Hole to central Texas and sparingly in the West Indies, and *Pagurus*, the hermit crab. At least three species of *Pagurus* occur today on Gulf shores in shallow water.

Rathbun (1935), recognizes several other recent genera, principally on the basis of meager fragments, in the Cretaceous. These include *Penaeus* (which goes back to the Jurassic), *Petrochirus*, *Dromia*, and *Menippe*. *Petrochirus* and *Dromia* are found today in the shoal waters of the Gulf, and *Menippe* is found especially in lower parts of the bays. *Penaeus* is represented today by several extremely abundant species, which support the major commercial fishery of the northern Gulf coast. Most members of this genus are characteristically euryhaline, the adults spawning in the oceanic or near-oceanic salinities while the young migrate into the bays and estuarine areas which serve as nursery grounds.

While *Penaeus*, *Upogebia* and *Menippe* have rather broad salinity tolerances, the modern representatives of most of the other genera identified from Cretaceous remains are stenohaline, tropical or subtropical species. Since the crustaceans are less likely candidates for fossilization than molluscs, corals and similar organisms, these scattered and incomplete remains indicate an abundant crustacean fauna in Cretaceous times. This fauna of reef-frequenting lobsters, shoal-water crabs living on sandy bottoms and mud-borrowing shrimps suggests that the Cretaceous provided as varied an array of physical environments as the present.

It is the general concensus of paleontologists and paleoclimatologists that Cretaceous times were on the whole warmer than the present and that tropical conditions prevailed in comparatively high latitudes. Two marine faunal regions are recognized for the late Cretaceous of the northern hemisphere according to Davies (1934), the "boreal," and the central or Tethys region. The "boreal" is represented by the chalk deposits of northern Europe, and the American deposits from New Jersey to Texas. The central or equatorial region occurred in the Mediterranean through the Near East and across the Caribbean to Colombia. Possibly it girdled the globe. The use

of "boreal" for the northern Cretaceous province is an unfortunate term since it carries with it the implications of our own boreal climates; whatever the climate was like, it was probably not "boreal" except in a relative sense. It is interesting to note that then as now the Texas region was apparently close to a borderline between two major faunal regions.

There seems to have been much less seasonal fluctuation than at present. According to Eckhardt (1909), seasons did not become well marked until the middle of the Cenozoic, and even at that time were much less pronounced than today. This does not preclude the probability of irregular fluctuations in rainfall with attendant effects on the salinity cycle of inshore waters, and it would certainly seem that estuarine conditions were developed in Cretaceous times. Reef-building pelecypods, the rudistids and ostreids, *Exogyra* and *Gryphaea*, were as characteristic of the shallow Cretaceous seas as the ammonites. Part of the basic ostreid stock must have been euryhaline at least by Cretaceous times. There may have been—and probably were—times when the environmental conditions fluctuated less than at other times, yet the total range of fluctuation could not have been completely beyond the range of tolerance of the basic stock. This stock is extremely conservative, to judge from the evidence of shell structure. Some Cretaceous oyster shells are similar in appearance to those found along the shores of "Recent" Texas and Louisiana bays.

Stenzel (1949), in discussing the paleoecology of oysters, suggests that the "brackish water environment is a highly specialized environment into which only a few hardy species can penetrate." It is true that brackish water fauna consists principally of a few hardy species, but in the case of the oysters, at least, it would seem that some of the various stocks have flourished in this environment and that some of the divergent lines have come from such estuarine stocks. While the environmental changes may bring about changes in the limits of tolerance in a stock, it is probable that the optimum requirements of the stock within this range of tolerance change much more slowly.

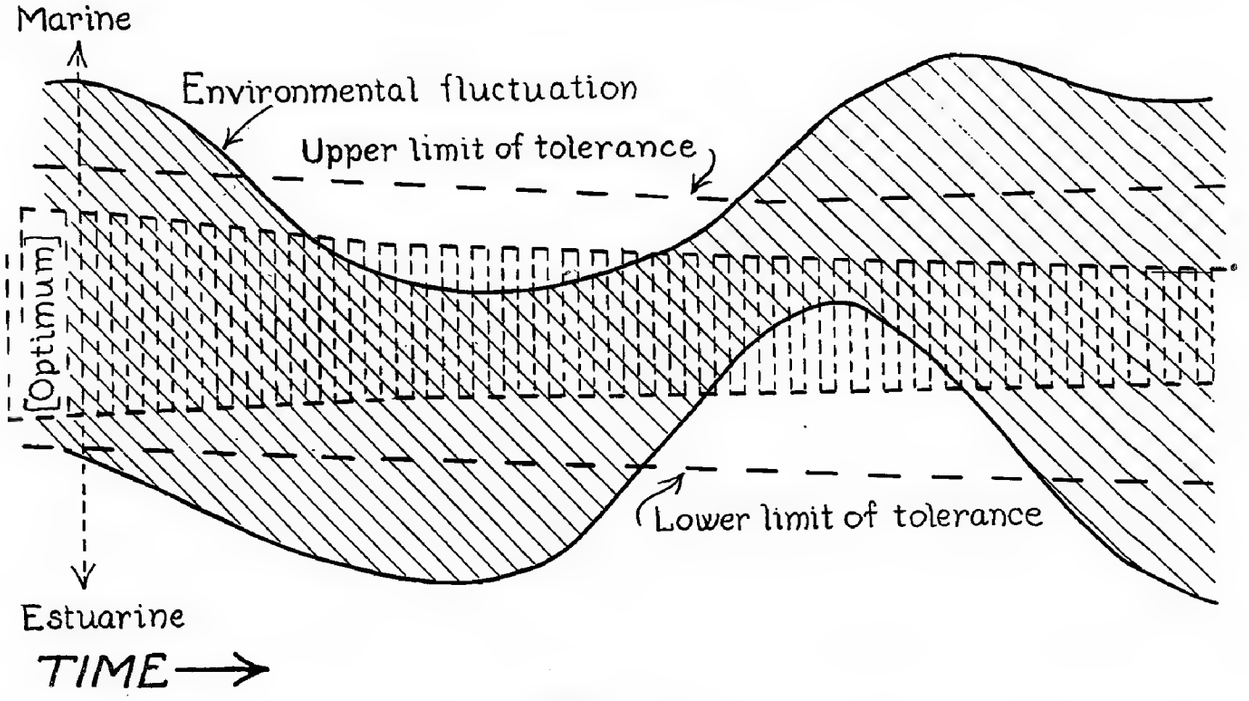

FIGURE 4

Diagram showing suggested relationship between optimum, range of tolerance and range of environmental fluctuation producing a gradual narrowing of the optimum range in an adaptive stock.

The possible relationship between the optimum, tolerance, and environmental change may be somewhat as indicated in the accompanying diagram (Figure 4). Although at the present time there are environments in which populations of *Crassostrea virginica* are approaching the limits of tolerance, as for example, in certain Louisiana waters, such conditions cannot be used as bases for sweeping paleoecological inferences. Certainly this oyster cannot be said to belong to one of those spent races which Annandale (1922) suggested find their last refuge in brackish waters.

It appears, from Stenzel's description of the reefs in which the *sellaeformis*-stock occurred, that this offshoot of the *Ostrea*-stock was probably stenohaline, and during the time of its development, the environmental change for the parental stock had swung toward the saline side. There are at the present time marginal beds of *Crassostrea virginica* in lagoons where the salinity is near the maximum tolerance for this oyster, and contain assemblages of invertebrates which are reminiscent of Stenzel's description of the "multi-specific" *Cubitostrea* beds. The oysters in such beds (*e.g.*, near Port Isabel, Texas) are thin-shelled, with knife-like edges, and appear to be smaller as a rule than oysters in less saline bays. This development of thin, angular shell structure is not necessarily an indication of high salinity, but may also indicate sheltered waters. Barnacles *(Balanus eburneus)* living in the sheltered waters of the Laguna Madre at 50–60 o/oo and in Copano Bay at less than 20 o/oo develop large, sharply pointed valves in both environments.

According to Stenzel, oysters of the *Cubitostrea* stock appear to have been marine, and to have inhabited "the lower part of the zone of wave action in front of the barrier beaches which separated the Tertiary Gulf of Mexico from its lagoons." It seems more probable that they lived in lagoons of near-oceanic salinity; the front of the barrier beaches is an area of shifting sand bars unfavorable to bivalves incapable of burrowing in the substrate. Living oyster reefs occur outside the barrier beach only in such localities as Marsh Island, Louisiana, where the physical conditions are atypical. Whatever may be speculated about salinity and temperature conditions, it cannot be presumed that equilibrium phenomena of the barrier beach were different in the past. The oysters may have also lived in or near the passes, which would explain the occurrence of the heavy, battered shells of *Cubitostrea* mentioned by Stenzel (1945a).

3. The Tertiary

The present Gulf of Mexico can be traced back to the orogenic and erosion interval which closed the Cretaceous period. At this time the seas receded from their greatest stand over North America and the present southward erosion pattern was established. During this uplift of land and retreat of the sea the larger part of the coastal plain was probably land, as there is a pronounced break in the fossil record between Cretaceous and Eocene faunas in this region (Stephenson, 1928). Since the Eocene there has been no apparent break in the continuity of the sea along the Gulf Coastal plain. Transgressions and regressions of the sea have been numerous; the peninsula of Florida has appeared and disappeared; the mid-continental drainage has discharged its sedimentary load into the northern Gulf throughout the Tertiary, and the basement formation of the Gulf of Mexico has steadily subsided.[2]

[2] There are several theories concerning the manner in which this subsidence has taken place. A popular theory is that of coastal downwarping at the landward edge of the continental shelf, resulting in or accompanied by the formation of the Gulf Coast Geosyncline (Barton *et al.*,

Although oysters continue to be as characteristic of fossil assemblages along the Gulf Coastal Plain as they are of Cretaceous deposits, the fossil record has in other respects changed almost completely. Of the various molluscan groups which were so conspicuous in Mesozoic seas, only some of the oysters survived in force. Many groups of mollusca which are important elements of modern assemblages made their appearance in the Tertiary, and genera are recognizable by Miocene time: "genera of lamellibranchs of the temperate regions can be traced to the Miocene, subfamilies to the Eocene, and families, at least in many cases, to the Cretaceous. Few Eogene genera can be confidently recognized in the Cretaceous and then only in the Upper Cretaceous." (Stewart, 1930).

There are, of course, exceptions. One of these, the genus *Nemocardium*, is discussed by Keen (1950). This genus arose in the Cretaceous, flourished in the Eocene (including eight species in the southeastern United States), and is now reduced to a single species, found in Japanese waters. This is similar to the history of the Crustacean genus *Linuparis*. There seem to be more examples of long-lived crustacean genera than of molluscs, as already indicated in the brief consideration of Cretaceous decapods. Whether or not this may be an artifact of differing taxonomic criteria in assessing the characters of Crustacea and molluscs, it nevertheless appears that Cretaceous and Paleogene Crustacea have a more familiar look than the molluscs. With the appearance of faunal elements more closely resembling modern forms, paleoecological inferences can be drawn which are probably more closely approximate than those from the fossil record of the Cretaceous.

Tertiary climates were as a whole warmer than those of the present, according to all indications, but perhaps somewhat cooler than those of the Cretaceous. Measurements of C_{14} by Urey *et al.* (1951) also indicate a decrease in temperatures at the close of the Cretaceous. Nevertheless, there is no evidence of an abrupt change of climate between the Cretaceous and the Tertiary, and were it not for the disappearance of the ammonites from the sea and the dinosaurs from the land, it would be difficult to draw the sharp lines between these periods found in the diagrams of the geological column in textbooks. There are, indeed, local examples of marine Cretaceous survivals well into the Paleocene in various parts of the world, but these are not common. Such conditions seem to be more common in fresh water facies (see Davies, 1934, Ch. III). The most characteristic indication of the end of the Cretaceous is the retreat of the

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1933; Wollard, 1936; Haeberle, 1951). In his luxuriantly terminological monograph, Kay (1951) classifies the Gulf Coast Geosyncline as a paraliageosyncline, accepting the geosyncline hypothesis wholeheartedly, although conceding the hypothetical character of the southern margin of this formation.

Recently Weaver (1950) proposed a theory of subsidence by downfaulting, "localized most intensely along the continental slope west of Florida, and the slope adjacent to Yucatan, and that along these major lines the greatest single displacements took place, but that even where the continental slope is less steep, it is a zone of faulting, possibly at several periods. . . ."

Another hypothesis (Dietz, 1952) which seems to explain the available data more adequately than the geosyncline concept or dropping the bottom out of the Gulf, is that the present configuration of the shelf and slope of the northern Gulf of Mexico is the result of prograding of coastal deposits across the shelf and the building up on a fan-like apron of deep-sea sediments against the continental slope. The isostatic subsidence of sediments deposited at the base of the continental slope is considered to be primarily responsible for the downwarping of the continental margin. The rough topography of the slope off Texas is thought by Dietz to be due to rejuvenation of an "old age" slope by the formation of a fault near the base of the slope so that it is now being degraded by marine erosion.

Older theories and data on the Gulf of Mexico and neighboring regions are summarized by Schuchert (1935), and Carsey (1950).

sea in various parts of the world including the Gulf of Mexico. The Tertiary was a period of regressions and transgressions of the sea in the Gulf province. According to Gardner (1935), "toward the close of the lower Miocene or the opening of the middle Miocene, the waters of the later Tertiary Gulf of Mexico withdrew to approximately the present shore line." Some idea of the possible shore line changes during the Tertiary can be gained from the postulated Florida shore lines of Cooke (Figure 5).

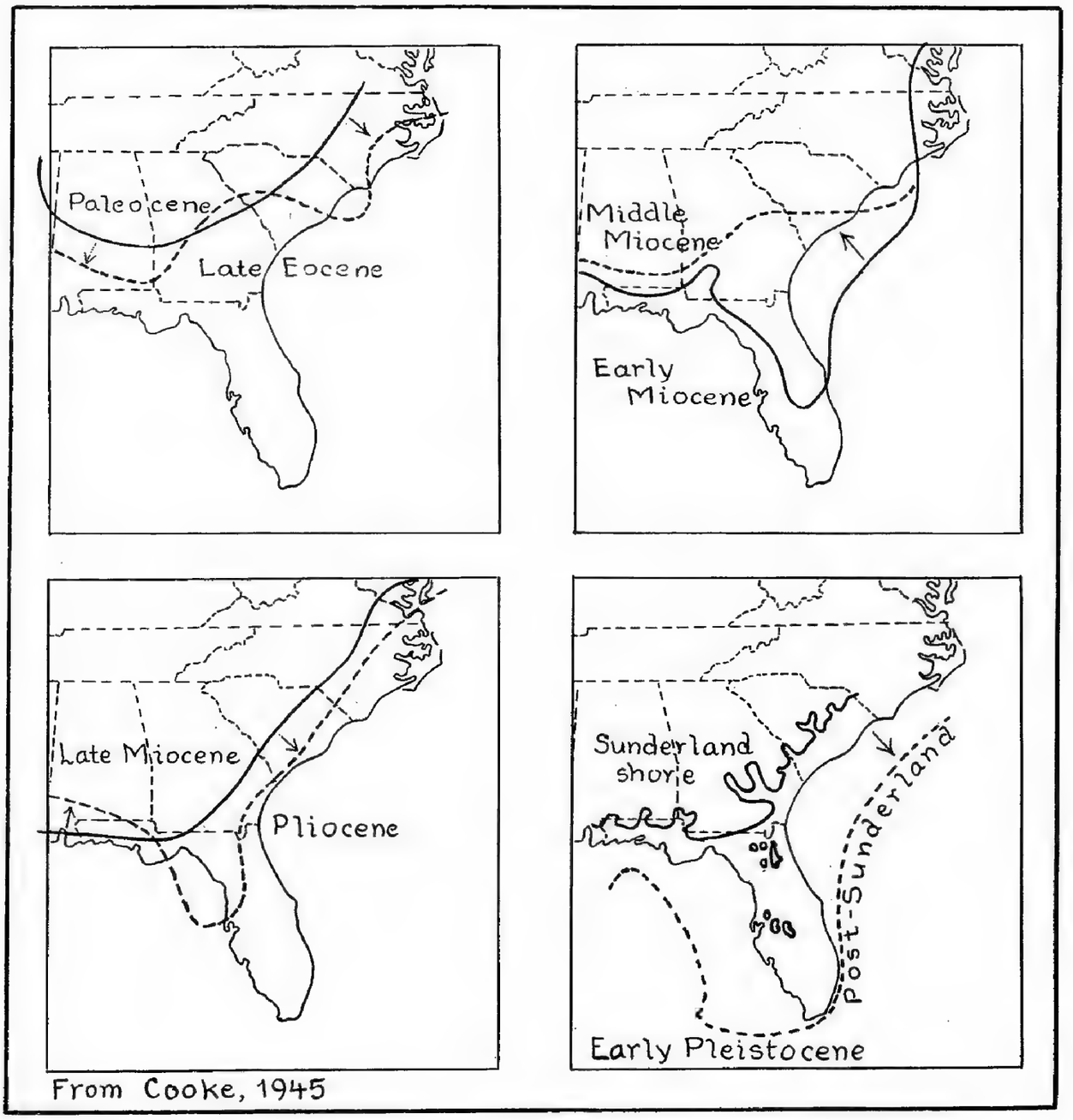


FIGURE 5

Postulated shorelines in Florida, according to Cooke (1945). The solid line in each panel indicates the earlier period, the dashed line the shoreline of the succeeding period.

Of particular importance to biogeographers concerned with distribution problems in the Gulf of Mexico are the paleogeographic changes which have occurred in the Caribbean-Antillean area during the Cenozoic. The marine biogeographer is concerned with oceanic continuities and temperature conditions which prevailed in past epochs.

Simpson (1950) finds no evidence for a complete isthmus during the Tertiary, or, to put it another way, he can best explain the history of the mammalian fauna of Latin America on the basis of a persistent "seabarrier" of varying efficiency. The close relationships between many elements of the marine fauna of the Caribbean and Panamanian regions support the evidence of the terrestrial fauna for marine connections during Tertiary times. A sea connection across northern South America through the Bolivar geosyncline, especially from lower Oligocene to Middle Miocene times, is suggested by marine assemblages in this region (Nygren, 1950). The relation between the marine faunas of both sides of Central America was a problem of particular interest to that pioneer explorer of the Gulf of Mexico, Alexander Agassiz, and to this interest we may trace the lists of species common to Atlantic and Pacific sides in such works as Faxon (1895) and Rathbun's monographs on crabs. The origin of the west American echinoderm fauna in relation to Tertiary connections with the Caribbean is discussed in some detail by Gislén (1944, pp. 54–77). Since the work of Agassiz no one has denied a separation of the continents during some if not all of the Tertiary, although Schuchert prepared a map indicating a rather broad connection in lower Eocene time (Figure 6). The subject of the Panamanian barrier is summarized in Hesse *et al.*, (1951, p. 126) and Ekman (1953, pp. 30 ff).

The Cenozoic marine climates of the northeastern Pacific have been studied by Durham (1950), who finds, principally on the basis of the occurrence of reef-coral types, a gradual southward recession of tropical temperatures since the Oligocene. During the Pliocene the isotherms attained the approximate latitudes of the present, and fluctuated during the Pleistocene. Circumstances appear to have been somewhat different in the Gulf province, although the interpretations are based on different criteria and the correlations are vague. In her studies of the Alum Bluff group (mid-Miocene), Gardner (1926) considers the Chipola formation a subtropical assemblage, followed by the Oak Grove, with a "fore-shadowing of the radical fall in temperature at the close of the Alum Bluff epoch which permitted the Mollusca of the Maryland province to penetrate the Floridian waters and to continue for a short time in this new environment." According to Vaughan (1910), "in Miocene time it is definitely known that a cold inshore current found its way southward to Florida and westward to Pensacola." Local conditions were, according to Gardner, somewhat variable in the later periods of the Alum Bluff. Although correlation of Cenozoic deposits on the Atlantic and Pacific sides of North America is not possible at this time with any precision, it appears from the correlation charts of Atlantic (Cooke, *et al.*, 1943), and Pacific (Weaver *et al.*, 1944), formations that the Alum Bluff group is roughly approximate to the Vaqueros and Temblor formations of the Pacific Coast, that the closing period of the Chipola was somewhere near the opening periods of the Temblor.

At this time, according to Durham's studies, the 20° winter isotherm was between 35° and 38° N lat. (between Pt. Concepcion and San Francisco). Certainly the presence of small coral reef formations in the Chipola, as indicated by Vaughan (1919), suggests that the 20° C isotherm was somewhat north of its present position in Florida. How far south it would have to move in the following period to enable Maryland province mollusks to live in the same region is a difficult question to answer; the present minimum isotherms of the Atlantic coast between Hatteras and New Jersey are 15 to 7° C and the southward movement of such isotherms would not have permitted even the slight reef development of the Oak Grove and Shoal River faunas.

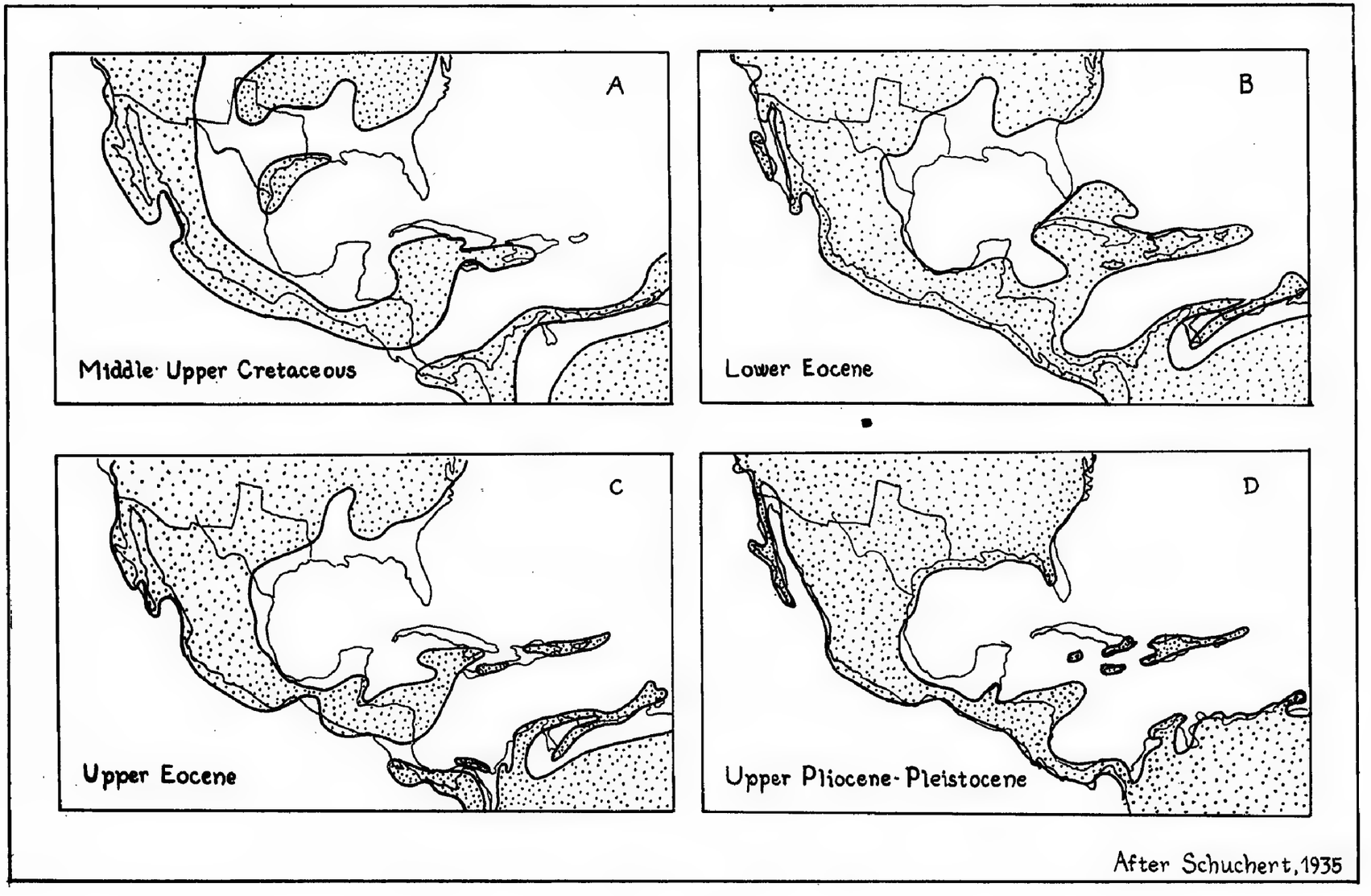


FIGURE 6

Phases of Antillean-Caribbean paleogeography, according to Schuchert.

Of course, this is a matter of degree, and the extreme interpretation placed upon the work of Gardner and Vaughan by von Ihering (1927) who suggests temperatures of 19–20° for the Caribbean during glacial epochs seems to be an unwarranted extension of the data. That there was indeed a cooler period in the later Alum Bluff appears evident, but it does not seem likely that there was a southward cold current of the magnitude postulated by von Ihering. It would also appear that Durham's temperature estimates may be slightly high.

During the mid-Miocene, according to Nygren (1950), the Bolivar seaway across northern South America was closed, and the appearance of high mountains forced cold currents to pass nearer the coast line on the Pacific side. Simpson (1950), however, finds indications of a complete separation of North and South America during the Miocene; perhaps this gap occurred farther north. A water barrier to terrestrial vertebrates is not necessarily a passageway for large water masses, and Burkenroad has offered the suggestion on the basis of the penaeid faunas (in Schuchert, 1935 and in more detail in Burkenroad, 1936) that deep water exchange between the Atlantic and Pacific was cut off at the close of the Mesozoic and that the connections were neritic in character during the Cenozoic.

Tropical or warm water assemblages, often also indicative of shallow protected seas, occur, according to Gardner (1945), in the Late Eocene, Lower and Middle Oligocene and Lower Miocene of northeastern Mexico and south Texas. Oysters are as characteristic of these formations as anything else, either in massive reefs or with various solitary corals. Most of the mollusks of the Gulf Coast Tertiary belong to the same genera found along the northern coast today, but few Recent species are recognized before the Pliocene. At this time *Crassostrea virginica* enters the scene. Gardner's

TABLE 2

Recent Mollusca found in the Alum Bluff (Mid-Miocene), Florida

Species*	Stratigraphic Occurrence*	Page ref.*	Present Range†
Pelecypoda			
Leda acuta (Conrad)	Chipola formation	12	Mass. to West Indies
Arca occidentalis Philippi	Oak Grove & Shoal River	23	N. Car., W. I., Gulf of Mexico
Arca umbonata Lamarck	Chipola & Oak Grove	24	N. Car., W. I., Gulf of Mexico
Barbatia reticulata (Gmelin)	Chipola & Shoal River	27	N. Car., W. I., Texas
Barbatia adamsi Dall	Chipalo, Oak Gr., Shoal R.	28	N. Car., W. I.
Glycymeris pectinata (Gmelin)	Shoal River	38	N. Car., W. I., Texas
?Pododesmus rudis Gray	Chipola	55	Fla., Bermuda, W. I.
Pseudochama arcinella Ohdner	Shoal River	94	N. Car., W. I., Texas
Phacoides trisulcatus (Conrad)	Chipola & ?Oak Grove	108	N. Car. to Brazil
Diplodonta nucleiformis (Wagner)	Chipola	118	Hatteras to West Indies
?Tellina aequistriata Say	Chipola	192	N. Car. to Brazil
Gastropoda			
Volvula oxytata Bush	Chipola & Shoal River	267	Hatteras to Cuba
Bulla striata Bruguière	Chipola	272	Clearwater, Fla.
Calyptraea centralis (Conrad)	Chipola, Oak Gr., Shoal R.	562	N. Car. to Gulf Mex., W. I.
Crepidula fornicata (Linnaeus)	Chipola, Oak Gr., Shoal R.	564	Pr. Edw. I. to Texas, W. I.
Crepidula plana Say	Chipola, Oak Gr., Shoal R.	565	Pr. Edw. I. to Texas
"Circulus" trilix Bush	Chipola & Shoal River	600	Hatteras to Port Aransas, Texas
Rissoina browniana d'Orbigny	Chipola	604	C. Lookout to St. Thomas, G. Mex.
Chlorostoma exolutum (Conrad)	Chipola & Oak Grove	616	Fla. Keys & W. I.
Lucapinella limatula (Reeve)	Chipola	622	Cape Fear to Key West, W. I.
Scaphopoda			
Dentalium eboreum Conrad	Chipola & Oak Grove	626	Hatteras to Sarasota, Fla.

* Compiled for the author by Julia Gardner (references to *U. S. G. S. Prof. Paper 142*)
† Compiled from Johnson (1934)

catalogue of the Alum Bluff of Florida (1926–47), includes about 20 modern species (Table 2), most of which are today subtropical or widely distributed eurythermal species. Rathbun (1935) identified at least 9 living species of decapod Crustacea from this formation. These include three, possibly four, species characteristic of shallow waters of oceanic salinity, and five species, including *Callinectes sapidus* and *Panopeus herbsti*, characteristic of estuarine waters.

Interpretation of Gulf Coast Tertiary fossil assemblages is further complicated by the occurrence of brackish water deposits, sometimes intermingled with fresh water deposits. A fauna of this intermingled sort is described by Stenzel and Turner (1944) from the Miocene of Newton County, Texas. Somewhat similar living assemblages can be found on the Louisiana coast where shifting river drainages may reduce the salinity to such a degree that oyster reefs will be killed off and fresh water—or nearly fresh water—animals can live on a substrate of oyster shells. An example of this is the Point au Fer reef at the southeastern corner of Atchafalaya Bay. The reef surface is made of tightly packed oyster shells, but no live oysters are found. During a visit to this reef in December, 1950, no other marine forms could be found, but a live *Rangia*, a few small *Mytilopsis (Congeria)* and *Neritina* were collected. In the northern part of the bay, a few miles from this reef, such fresh water plants as water hyacinth and *Juncus* were growing (observations by J. G. Mackin, from S. H. Hopkins, personal communication).

Gardner's study (1945) of the northeastern Mexico Tertiary indicates, more strongly than she suggests, the synchronous existence of marine and estuarine conditions at several periods in this region, supporting populations of subtropical and eurythermal molluscs somewhat similar to the modern assemblages, with perhaps a somewhat stronger representation of warm water species than is found today.

4. The Pleistocene

The Pleistocene has been characterized by Flint (1947) as "the events of the latest million or more years in the history of the earth." The life of this period is essentially that of today, subject to the pronounced alteration of conditions brought about by the successive glacial periods. The fossil record is so confused and the stratigraphic position of most marine beds so uncertain that little can be concluded from the Pleistocene record of the Gulf coastal plain save that marine conditions have not been greatly different from those of today. Water temperatures were at times cooler, in all probability, since there is evidence that there have been periods of cooler, moister climates on land. Pleistocene assemblages in California indicate a northward and southward fluctuation of marine isotherms, in the magnitude of 2 or perhaps 3 degrees of latitude from their present position.

The influx of tropical water into the Gulf through Yucatan Passage and its deflection to form the Florida current is an important feature of the present epoch. Schuchert (1935) places the origin of the Gulf Stream in the closing epochs of the Tertiary, ascribing this event to the deflection of a Cretaceous trans-Panamanian equatorial current by the formation of a volcanic arc, the "Panama barrier," and the subsidence of the Antillean geanticline to form the Yucatan channel. Another writer who has attempted to explain the origin of the present current system is Brooks (1949), who attributes it to the northward deflection of the South Equatorial current by the wedge-like apex of South America. This configuration apparently existed

throughout the Quarternary, according to Brooks, who remarks, however, that "there is a considerable amount of evidence that during at least the early part of the Quarternary period the Gulf of Mexico was largely dry land." He seems to believe that this would have deflected the Gulf Stream, apparently failing to observe that the present current is deflected without a major land mass in the Gulf. Indeed, both of these theories of the origin of the Gulf Stream appear to have been drawn up without adequate consideration of existing current patterns in the Northern Hemisphere. At the present time more than half the water of the Gulf Stream comes directly from the Atlantic eastward of the Antilles without passing through the Caribbean or the Gulf. It is highly probable that equatorial currents of some sort passed over the isthmus during periods of submergence, but their magnitude was probably inadequate to satisfy the demands of the theories of Schuchert and Brooks.

During the glacial periods of the Pleistocene, when the sea level receded, Florida was a peninsula, and conversely, during the high stand of the sea during interglacial periods, Florida was in large part submerged (Figure 7). Since these changes in sea level occurred over the shallow Floridian plateau, there was probably no major shift in the axis of the Florida current. Counter currents probably existed across these shoals. It was probably some such pattern as this which made possible the dispersal of northern species into the Gulf of Mexico, together with a southward shift of the coastal isotherms. Deevey (1950) postulated a lowering of mean annual sea temperatures at Key West by at least 5° C, without taking the submergence of the Florida peninsula into consideration.

On the basis of his findings of the Foraminifera fauna of shallow cores from the northwestern Gulf of Mexico, Phleger (1951) finds indications of cold water conditions during the last glacial age, "but not as cold as in present arctic waters." He suggests that surface water temperatures were "considerably lower at all seasons than temperatures in the present Gulf of Mexico" during the period of deposition of the lower-core fauna. This conclusion is reached in a relative manner: "The presence of a lower 'cold water' fauna in any core is determined by comparing the lower Foraminifera assemblage with the fauna now living in the area. In middle latitudes such a cold-water fauna may be similar to a modern Arctic fauna; in low tropical latitudes, on the other hand, the cold-water fauna may be like a modern warm-temperate assemblage." (pp. 79–80). On such a basis, it is not possible to suggest any precise differences in mean temperatures at a given locality, and this is not attempted by Phleger, although his preliminary data have been used by Deevey in support of his suggestion of a lowering of at least 5° C in mean annual temperatures at Key West.

Such cooler conditions as existed may have been local; Pleistocene assemblages on Hispaniola, for example, indicate by the presence of numerous warm-water molluscs and corals, conditions not greatly different from those prevailing at present (Woodring, *et al.*, 1924; Vaughan *et al.*, 1921).

This "disjunct pattern," *i.e.*, the occurrence of non-tropical species on both sides of Florida but not in the southern part of the peninsula, apparently was as characteristic of Pleistocene periods when Florida was a peninsula as it is today. It is possible to select from Richards' (1939a,b) lists (in part a compilation of various sources) of Pleistocene molluscs from Florida and the Gulf States a number of disjunct species, including *Abra aequalis*, *Crassostrea virginica*, *Rangia cuneata*, *Littorina irrorata* and *Urosalpinx cinereus* (Figure 8). The last named species is unknown in the

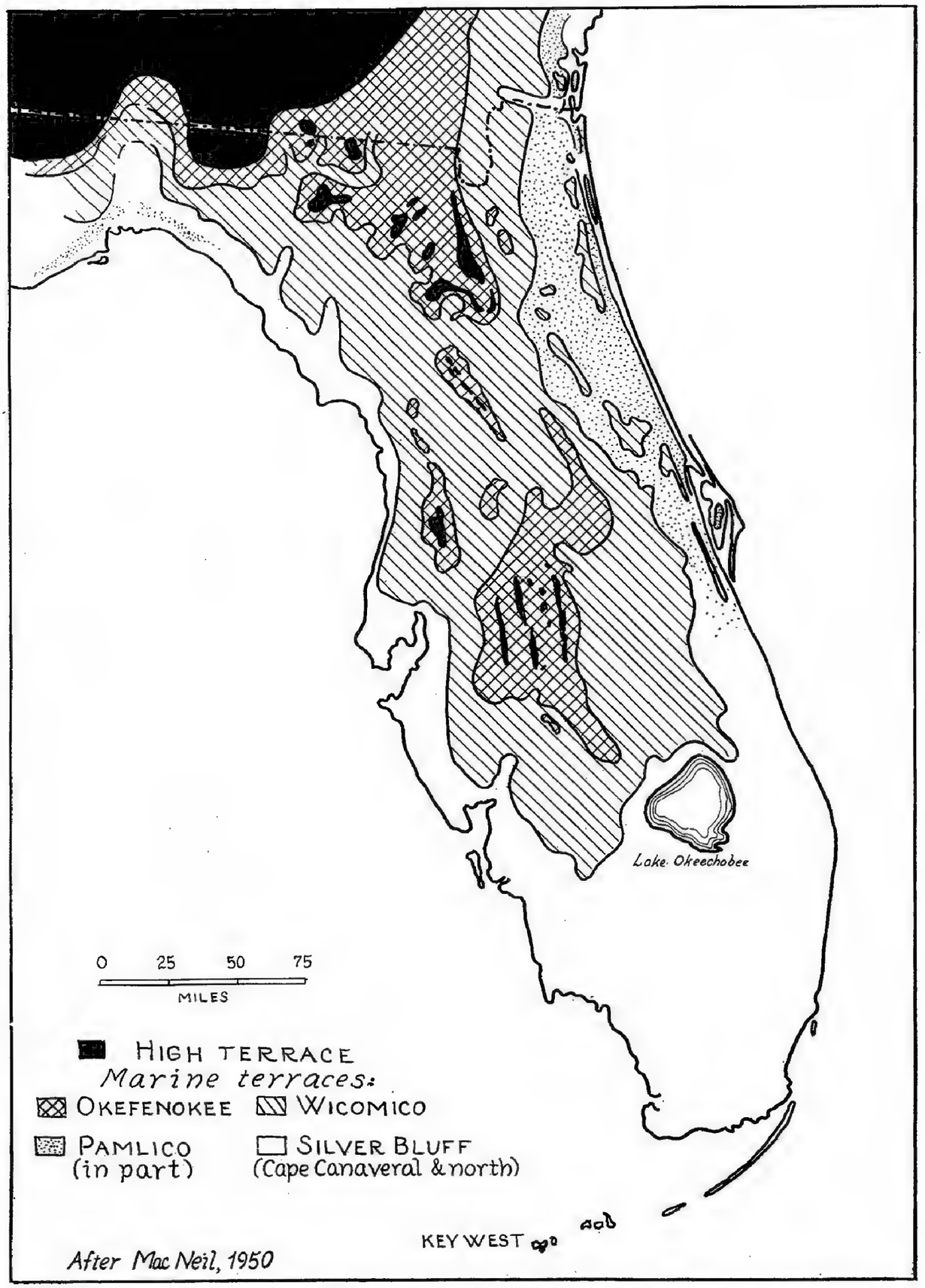


FIGURE 7

Map showing principal terraces and shorelines in Florida during Pleistocene times. Adapted from MacNeill, 1950.

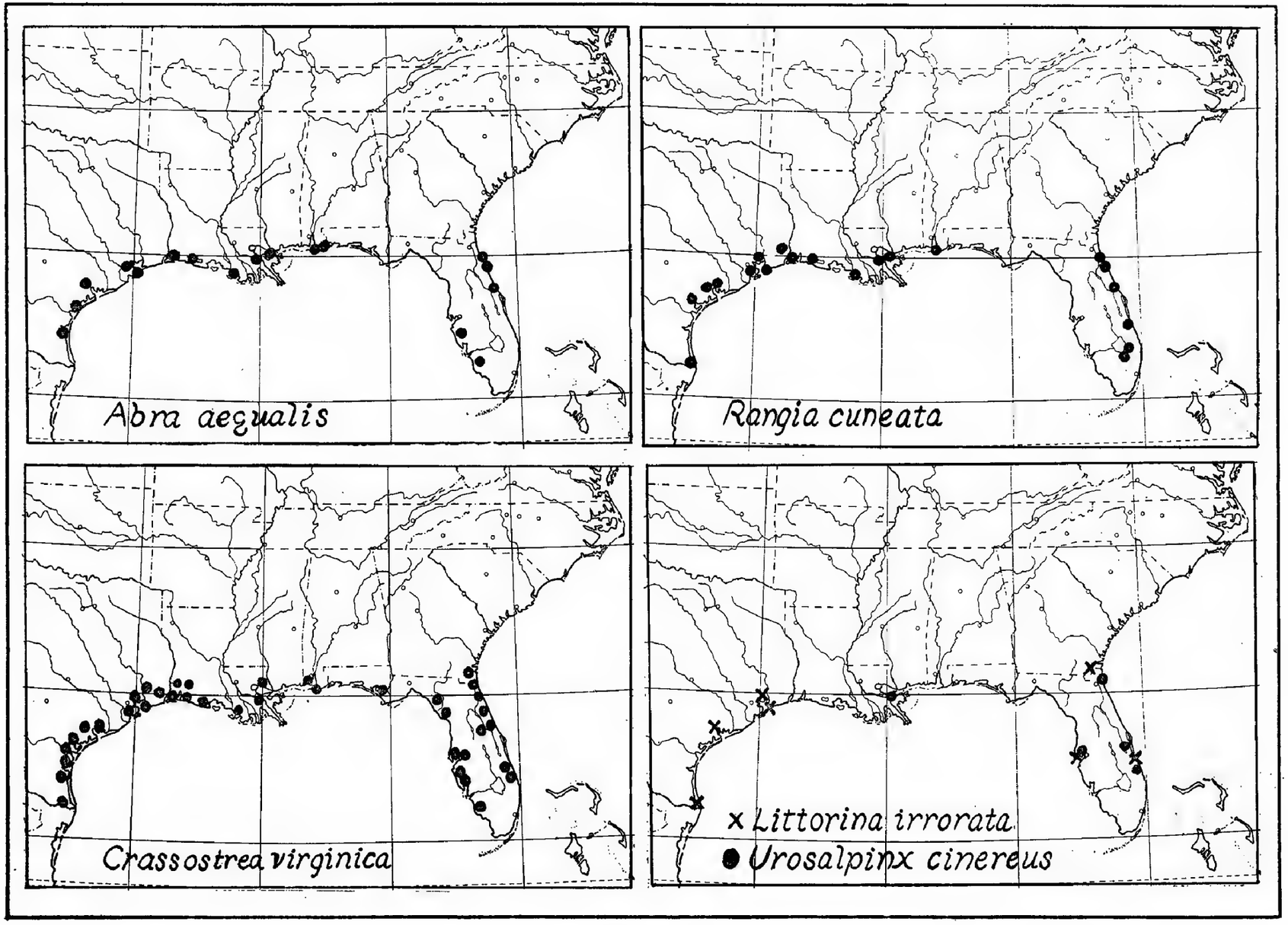


FIGURE 8

Pleistocene distribution of various molluscs in Florida and the Gulf States, compiled from Richards, 1939a, 1939b.

living fauna of the northern Gulf Coast although it is abundant on the middle Atlantic coast.

The distribution of *Rangia*, as determined by Richards, is of particular interest since it is an indicator of estuarine conditions. The present day occurrence of *Rangia* is at the borderline between fresh water lakes and low salinity bays, and its major populations are landward of the oyster environment. Pleistocene *Rangias* have been found at Port Isabel, where today the environment is almost too saline for oysters. Living *Rangias* occur in abundance at the present time as far south as central Texas, in various parts of the lower Guadalupe drainage. This mollusc does not seem to be as abundant in Texas as in Louisiana. The principal source of mudshell in Texas bays is oyster shell, while in Louisiana it consists of about 50% *Rangia* shells (Gunter, 1952). These are always in separate deposits. This so-called mudshell consists of extinct shell reefs, from near the surface to twenty to sixty feet below the bottom of the present bays. The shallow deposits are early Recent and suggest periods of more moisture than the present, while the deepest reefs are possibly glacial in age although their depth may be in places exaggerated by subsidence.

The interpretation of Tertiary and Pleistocene assemblages of the Gulf Coastal Plain is not a simple task; climatic fluctuations which may appear clear-cut in retrospect cannot always be localized with a given assemblage, and Pleistocene stratigraphy is more a subject of controversy than agreement. The summary provided by Fisk (Figure 9) is not universally agreed upon, and the correlation of coastal plain formations in such contiguous regions as Texas and Louisiana is still uncertain. These difficulties have been emphasized by Deevey's (1949) essay on Pleistocene biogeography. The most complete summary of the events of the Pleistocene is given by Flint (1947), whose book is the best source of information. Flint recognizes four glacial and three interglacial periods. The last glacial age, the Wisconsin, has two recognizable substages in the Lower Mississippi valley according to the interpretation of Fisk.

By Pleistocene times the transitional nature (in the marine biogeographic sense) of the environment of the Gulf coast, which may have been evident in the Cretaceous (Davies, 1934), was well developed, and the fluctuations in temperature and rainfall characteristic of such a transition zone had begun to leave their mark. At the present time mass mortalities due to killing cold spells, flooding of parts of the coastal plain bays or estuaries and high salinities in time of summer drought occur frequently enough to be considered a characteristic feature of this environment.

II

Environmental Conditions of the Present

1. Geomorphology

The coasts of Texas and Louisiana have been shaped by the same physical processes and exhibit the same geomorphic features. The differences in the appearance of the two coasts are the result of the differences in climatic regimes and river drainages, and of local differences in tilting. Basically, the northern coast of the Gulf of Mexico is a depositional shore line developed by rising sea level with resultant building up of deltas and other alluvial features since the last glacial period. This type of shore line was not recognized by Johnson (1919), who classified shore lines in four cate-

ERA	PERIOD	EPOCH	Duration (years)	AGE (interglacial)	Important characters and events
CENOZOIC	QUATERNARY	Recent (Holocene)	30,000	ALLUVIUM	*Cyclical changes in sea level associated with advance and retreat of continental ice caps cause alternating entrenchment and alluviation by rivers. Recent floodplain represents end of latest cycle. Epirogenic uplift inland and subsidence of coastal margin throughout the period.*
		Pleistocene	970,000	Late Wisconsin Peorian-Prairie Early Wisconsin Sangamon-Mont- Illinoian gomery Yarmouth-Bentley Kansan Aftonian-Williana Nebraskan	
	TERTIARY PALEOGENE NEOGENE	Pliocene-Miocene(?)	20,000,000		*Separation of deposits from Miocene questionable. Belted coastal plain topography continuing development.*
		Miocene		GRAND GULF	*Period of maximum delta growth. Shoreline retreated gulfward. Over 8,000 feet of deltaic sediments accumulated in southern Louisiana and constitute the thickest known single deltaic mass in Gulf Coast Geosyncline. Epirogenic uplift initiated development of braided topography.*
		Oligocene	6,000,000	VICKSBURG	*Widespread marine conditions gradually superseded by delta growth and seas gradually retreated from coastal plain. Thickest deltaic masses in southwestern Louisiana and adjacent parts of Texas.*
		Eocene	20,000,000	JACKSON	*Marine advance to vicinity of Memphis marks cessation of fluviatile sedimentotion in Mississippi Embayment.*
				CLAIBORNE	*Fluctuation of shoreline as sedimentation slackened. Deposits characterized by alternation of marine and deltaic deltaic deposits. Thickest deltaic masses in southwestern Louisiana and adjacent parts of Texas.*
				WILCOX	*Deltaic growth and retreat of shoreline. Thick deltaic deposits located in southeast Mississippi and in central western La. and Texas. Land areas standing high; geosyncline sinking.*
		Paleocene		MIDWAY	*Widespread thin marine beds show marine conditions existed inland to head of Mississippi Embayment. Land areas low during period.*
MESOZOIC	CRETACEOUS	Upper C.	40,000,000	Gulf series: NAVARRO TAYLOR AUSTIN EAGLE FORD WOODBINE	*Mississippi Embayment formed by down faulting. Fluctuating shoreline with the seas reaching inland to head of Mississippi Embayment. Deltaic accumulations thinner than those of the Lower Cretaceous and mark a gradual slackening of sedimentation.*
		Lower C.	30,000,000	Commanchean: WASHITA FREDERICKSBURG TRINITY (Glen Ford / Travis Pk.)	*Delta growth and retreat of shoreline. Centers in northern Louisiana and Arkansas and in Alabama. Sediments derived from highlands in Ouachita region of Arkansas and southern Appalachians of Alobama. Salt and other evaporite deposits present. Land areas high; sinking in geosynclinal regions.*
	JURASSIC		40,000,000		*Several thousands of feet of deltaic sediments penetrated by a few borings in the Central Gulf Coastal Plain. Marginal land areas probably rising. Salt and other evaporite deposits present. Coarse sediments mark position of shorelines.* (After Fisk, 1944)

FIGURE 9

Chart showing sequence of events in the central part of the Gulf Coastal Plain, according to Fisk (1944).

gories, those of emergence and submergence, and neutral and compound. The deficiencies of this classification are roundly denounced by Russell (1949): "The classical classification of shorelines is of little or no use to geographers, or anyone else. . . . It is firmly rooted, however, and several decades may elapse before it disappears from our textbooks." A revised classification was proposed by Shepard some years ago (1937).

This limited conception of shore line development led Johnson to interpret the Texas coast as a shore line of emergence, and to describe in some detail (Ch. VII, pp. 364–367), a theory of the origin of the barrier islands as a feature of a rising coast line. The usual interpretation of bar formation on a coastal plain is that it is an equilibrium phenomenon: "Most of our Atlantic and Gulf coast is now sand-reefed for the simple reason that the general slope of the Atlantic Plain is too gentle to afford a profile of equilibrium for shore processes. . . . Were the present barriers removed, the slope would, at many places, be essentially uniform. As it is, the relatively steep slope in front of the barrier about compensates for the flat lagoon behind." (Fenneman, 1938, p. 4.) Recent evidence suggests that the bars on the Gulf coast are formed by processes of submergence (F. P. Shepard, pers. comm.).

A. Louisiana

The barrier island structure is found in Louisiana in several places: the Chandeleur arc, Grand Terre and Grand Isle, Timbalier Isle and Isles Dernières. With the abandonment by the Mississippi of channels behind the barrier island and consequent retreat of the mainland shore, the barrier may move gradually toward the mainland. The lighthouse on the north end of the Chandeleurs has been moved four times in the last 150 years to keep pace with the landward migration of this arc. An old stage in this process is to be observed in the coastline to Terrebonne Parish, where the barrier island is in some places almost on the mainland shore (Island Dernières) and has actually reached the shore between Grand Isle and Timbalier. A still older stage, according to Russell (1948), is found on the coast near Cameron, where the remnant of the barrier island is now well ashore. Old beach ridges are conspicuous features of the landscape, rising several feet above the marshes and supporting stands of oaks and other brushy trees. These cheniers block the courses of streams and cause the development of ponds along their inner margins (Figure 10).

The present Mississippi Delta, peculiar among river deltas for its "bird's foot" shape, is more an artifact of engineering efforts to stabilize the river channel for navigation than a result of natural processes according to Russell (1948). Given its way, the lower Mississippi would turn from its present channel and develop a new delta at the mouth of the Atchafalaya, bypassing New Orleans. It is making every effort to do so; at the present time the Atchafalaya carries 25% of the discharge of major floods. Some idea of the results of the artificial stabilization of the lower Mississippi can be obtained from the changes in the shore lines and configuration of the delta which have occurred in historical times (see Figure 10). Fisk (1944) estimated that the silt load of the river is in the magnitude of two million tons per day.[3]

[3] The effects of attempts to stabilize the lower Mississippi on the hydrographic economy and fauna of the lower bays in the face of tremendous alluvial forces are incompletely investigated. The problem is complex; often changes in one area are beneficial in another. Possible harmful effects on oyster production were mentioned as early as 1907 by Cary (1907) and one example of mortality from crevasse (levee break) was described even earlier (Johnson, 1891). More recent discussions of this complicated and controversial subject have been provided by Butler (1949), and Gunter (1950d; 1952). Viosca (1928) suggested that the lowland basins of Louisiana should be dedicated "to floods, fish, and higher aquatic life."

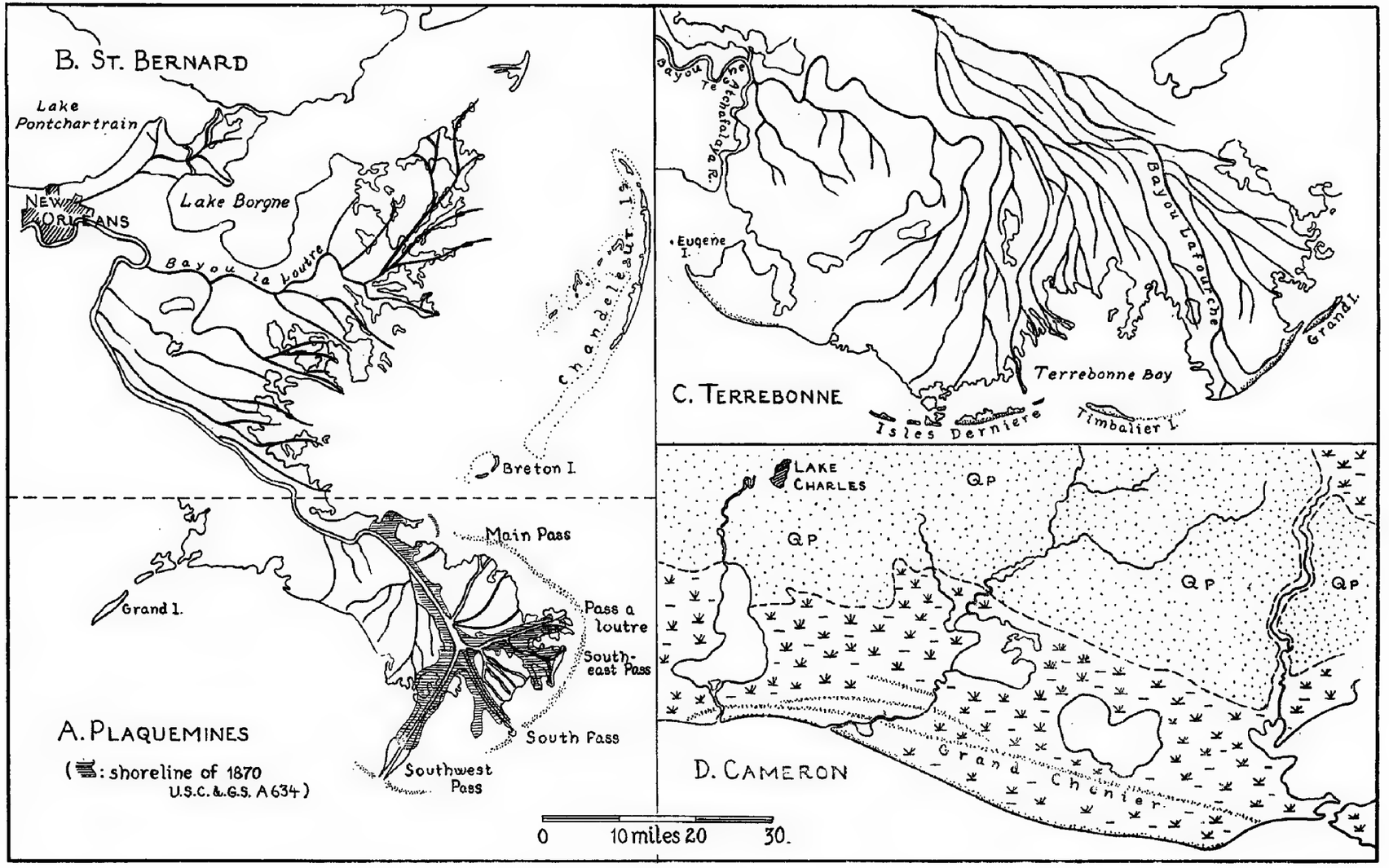


FIGURE 10

Shoreline stages in Louisiana, according to Russell, 1948, together with delta shoreline changes since 1870, from U. S. Coast and Geodetic Survey chart A 634. The panels A–D are modified from four separate figures by Russell; the parish names have been applied by Russell as "shoreline types": the order A–D indicates the suggested developmental stages from active delta to marsh land far to the west of the present active delta.

B. Texas

The barrier island, formerly called "offshore bar", fronts a coastal lagoon (Price, 1951). Under hypothetical conditions (without drainage) it may be assumed that the coast line would consist of a barrier island fronting a continuous lagoon without passes or inlets between the sea and the lagoon. The nearest approach to this model condition is found on the southern coast of Texas, where Padre Island extends for a distance of 130 miles, the longest unbroken barrier island in the world. From Corpus Christi northward the lagoon is broken up into bays. In addition to the segments of the coastal lagoon there are wider bays cutting across the former barrier island which was landward of the present one. These consist of embayed valleys or delta basins. Another type of bay, the inner or back bay, may be formed by rejuvenation of the earlier coastal lagoon. A more detailed description of these various tidal waters in Texas have been suggested by this author in an earlier paper (Price, 1933), and are summarized in Figure 11.

The outer shore line of the barrier island is almost straight in general aspect, but describes a long, concave arc on the Texas coast. Barrier island shore lines of the Louisiana coast are shorter, and describe shorter, convex arcs. Temporary serrations or cusps, sometimes several hundred feet apart, are caused by storm action, but may be straightened out by other storms. The inner shore line is irregular, scalloped by washover fans or prolonged into spits, which on the Texas coast, usually point to the southwest. Some of the spits may persist as "flying bars" of small chains of islands, *e.g.*, the Bird Islands of the Laguna Madre. The shore lines of Louisiana are more irregular, complicated by alluvial deposits and the extensive development of marshes and growths of black mangrove *(Avicennia nitida)*, so that it is sometimes difficult to decide the boundaries between land and water. In less humid regions there is a development of clay dunes, especially conspicuous as low hills 15–20 feet high in the vicinity of Port Isabel and south of Corpus Christi near Oso Bay (Huffman and Price, 1949).

The most conspicuous, and biologically significant, feature of the shore line is the tidal inlet. Along the Texas coast these inlets—or passes—become stabilized at the extreme southern end of the bays which they serve. Examples of such stable passes are Pass Cavallo, Cedar Bayou, and Corpus Christi Pass (which is now closed, probably because of the lower hydrostatic head resulting from the dredged inlet, Aransas Pass). Related to the inlet is the tidal delta, built up by deposition of sediment carried from the direction of the barrier island northeast of the inlet. Thus the delta is built up at the northern end of the island south of the inlet. Two of these tidal deltas are well developed on the Texas coast, that at Pass Cavallo, and Harbor Island, at Aransas Pass. The latter has been disturbed by channel dredging and jettying of the pass so that its present configuration is probably abnormal. At the time of white settlement, Aransas Pass was still in the process of migration, and was stabilized in its present position by jetties in 1887.

2. Hydrography

A. Climate and Salinity

The climate of the Gulf coast of the United States varies from a near desert, or dry subhumid, type in the southern part of Texas to the humid climate of Louisiana.

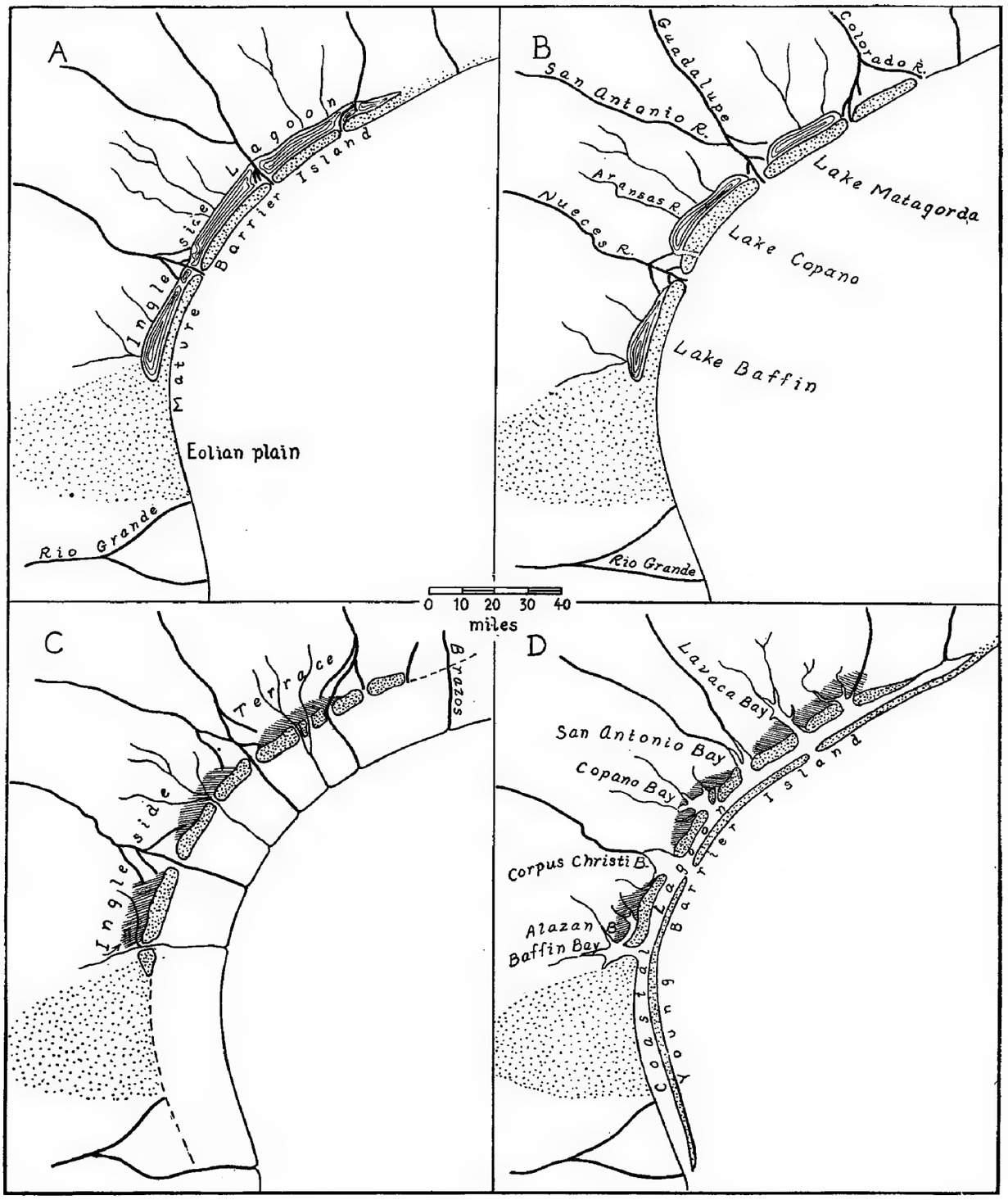


FIGURE 11

Suggested stages in the history of coastal features in Texas. (After Price, 1933.)

A. Stage showing mature barrier island retreated to shore, with master streams flowing directly into Gulf but with distributaries flowing into the lagoons.

B. In this stage the deltas have built up, partly filling the lagoons. At this stage the lagoons probably connected with the Gulf through narrow inlets.

C. With fall in sea level and retreat of shoreline the streams became entrenched from 50 to 75 feet, with little erosion of the broad, flat upland divides.

D. Following a rise in sea level the canyons are drowned and the estuaries widened into bays. The estuaries of the master streams developed bays with axes transverse to the coast line and those of the minor streams empty into longitudinal bays in the terrace behind the original barrier island or develop small tributary bays.

According to Thornthwaite's scheme (1948), the semi-arid type, characterized by conditions of more or less permanent moisture deficiency, extends from the Rio Grande to about 30° 30′ N, just south of Corpus Christi. The next type of climate, the dry subhumid, which is still for the most part a moisture deficient climate occasionally approaching a moisture balance, extends from Corpus Christi to the lower shores of Matagorda Bay in the vicinity of Port Lavaca. The transition from the semi-arid to dry subhumid climates is a gradual one on land. The mesquite and huisache are replaced by small oaks and various shrubs. In the bays, the dry subhumid climate is associated with the lower limit of optimum oyster growth, and as we proceed northward, the oyster reefs become larger and the oyster fishery increases to a maximum in Louisiana. The next climatic type encountered is the moist subhumid, which extends from Port Lavaca to Galveston on the Texas coast and comprises the principal climatic type of peninsular Florida. In this climate, moisture supply and loss are in balance, tending toward a moisture surplus. From Galveston to the Mississippi Delta we find a humid climate, the B_1 of Thornthwaite, with a moderate moisture surplus. A still moister climate, humid B_2, is found north of the Delta and along the coast eastward to Choctawhatchee Bay (Figure 12).

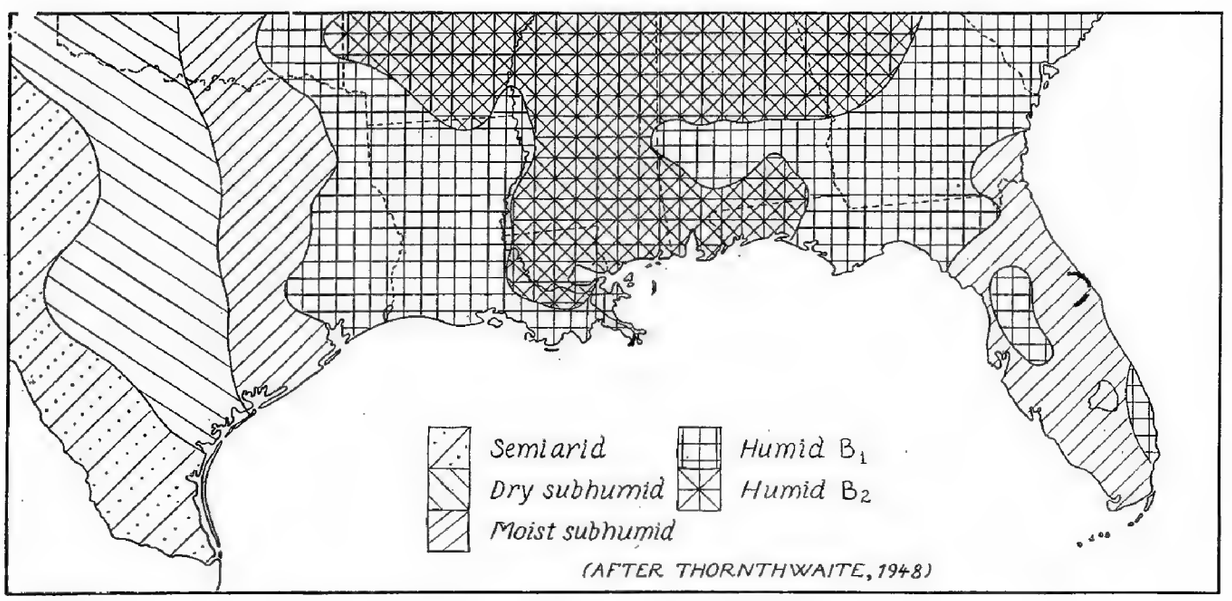


FIGURE 12

Climatic types of the Gulf Coast, according to Thornthwaite, 1948.

Along the Gulf coast, at least, these various climatic types are roughly correlated with rainfall, and their limits correspond with the 25-, 30-, 40-, 50-, and 60-inch isohyets, respectively (Figure 13). Inland, however, the correlation breaks down. Since the river drainages which influence the conditions in the various bay systems in this region transgress climatic and rainfall regions, it becomes necessary, for the purposes of detailed analyses, to consider each system as a unit. An example of this treatment is that of Collier and Hedgpeth (1950), for the Aransas Hydrographic System of the central Texas coast. According to the data of the U. S. Coast and Geodetic Survey (1949), salinities average from 4.2 o/oo at Eugene Island, near the mouth of the Atchafalaya, to 33.6 o/oo at Port Isabel, and correspond, as might be expected, with the rainfall conditions. There is little information available on

the influence of the main stem of the Mississippi on the salinity regime of coastal waters (*cf.* Burkenroad, 1939, pp. 2–4). The study by Geyer (1950), indicates the profound effect of this drainage, since his data were obtained from a depth of ten feet from oil well platforms five miles offshore. Surface salinities at these stations are probably lower. At Eugene Island, during periods of high flow in the Atchafalaya distributary, salinities are often reduced to zero, and average 0.7 and 0.8 o/oo in some months (Figure 14).

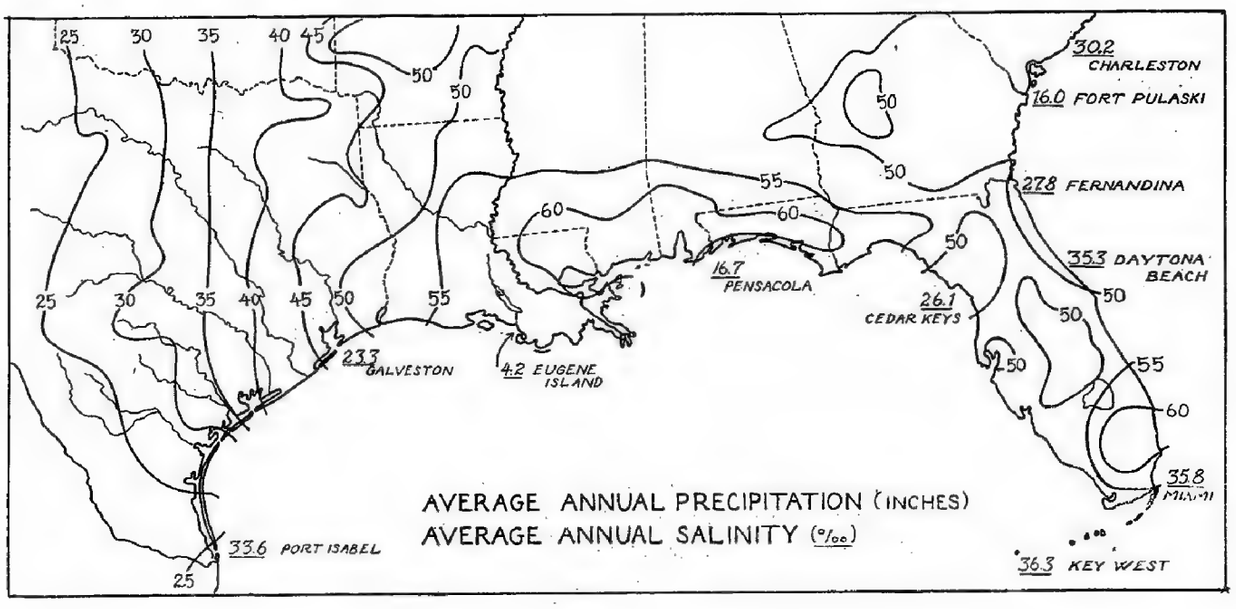


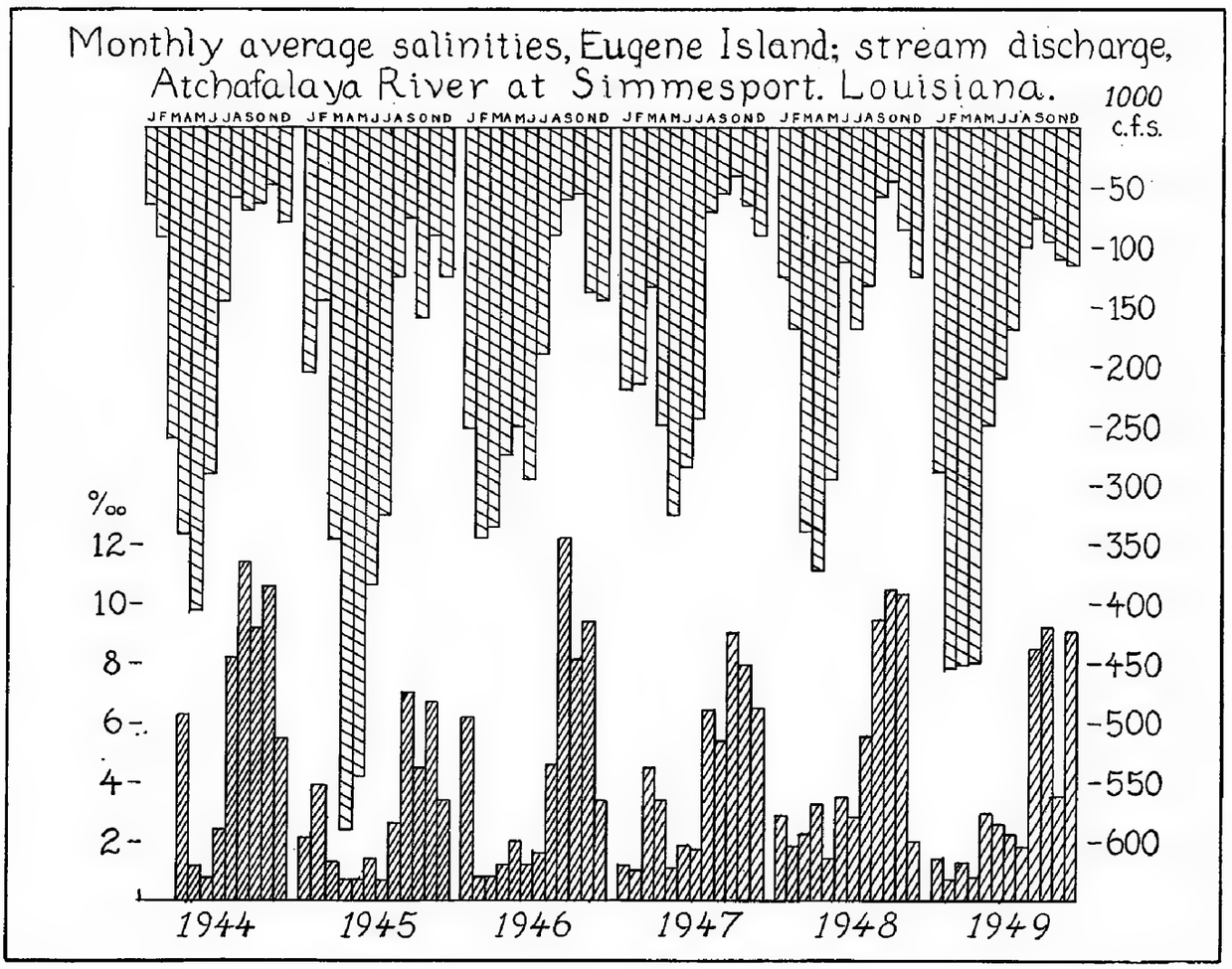
FIGURE 13

Average annual precipitation, Gulf states, and average annual salinities at designated localities. Compiled from U. S. D. A. Yearbook for 1941 and U. S. C. & G. S. density tables, 1949.

Such changes may be sudden and of short duration. Geyer noted variations as great as 19 o/oo within a period of one or two days, and also changes occurring within a few hours. Such changes are characteristic of the coastal and tidal waters in the delta area. Variations in salinity are less pronounced, at least in frequency, in Texas waters. Salinity conditions are nearly stable at Port Isabel, where the monthly averages range from 30.4 to 37.5 o/oo. Variation is the rule, however, in most of the tidal waters of the Gulf coast. The comparatively stable brackish water conditions of such regions as the Baltic Sea or the low salinity conditions of the Black Sea are not found in this region except perhaps in a few isolated basins. Conditions are, in other words, estuarine rather than "brackish." Even in Baffin Bay, where salinities are around 50–70 o/oo, there may be sudden decreases after heavy rains, to as little as 2.2 o/oo (Gunter, 1945a, p. 49).

The least variable salinity conditions for which there are records in the Gulf of Mexico are those at Key West, where the average range is from 35.2 to 36.6 o/oo and the extremes range from 28.0 to 38.8 o/oo. The average surface salinity of the Gulf of Mexico as a whole is at least 36 o/oo. Sverdrup *et al.* place the 36 o/oo isohaline between Honduras and Hispaniola (1942, Chart VI). Parr (1935) indicates the salinity of the Gulf during February–April, 1932, as being 36.0–36.25 o/oo, and Phleger (1951) gives a range of 36.25–36.35 o/oo for the offshore

waters of the northwest Gulf during January–March, 1947. The salinities of inshore waters near Corpus Christi were found to be around 31.0–33.0 o/oo.


Monthly average salinities, Eugene Island; stream discharge, Atchafalaya River at Simmesport, Louisiana.
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1945
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1949

FIGURE 14

Relation between river discharge at Simmesport, Louisiana, and salinities at Eugene Island. Stream flow data courtesy Mississippi River Commission; salinity data from U. S. Coast and Geodetic Survey density tables (1949).

The normal distribution of climatic types, especially in Texas, may suggest more stable conditions than actually exist. Fluctuation of climates from year to year are the rule rather than the exception. These variations, from 1900 to 1939, have been indicated on a series of maps by Thornthwaite (1941). The variation in climate at Corpus Christi, "normally" lying in the subhumid belt, has been worked out on a percentage expectancy basis for a hundred year period by Price (1949):

Desert	Semi-arid	Dry Subhumid	Moist Subhumid	Humid
5	34	43	10	8

This indicates that the expectation of "normal" climatic years is less than 50%. In the last five years Texas has been experiencing drouth conditions, with rainfall well below normal and temperatures consistently above normal. This is reflected in the recent salinity averages for Rockport. While these averages are for a single locality, the records are roughly comparable to the earlier averages for Aransas Bay (Table 3).

As this table indicates, there are unfortunately but two years for which there are salinity records for all twelve months. The best data are probably those for 1938. Inspection of Thornthwaite's Atlas reveals that this year was somewhat drier than normal in Texas, and hence these readings may be presumed to indicate slightly higher average salinities than normal for this year in Aransas Bay. The most recent available data for this region indicate salinities of over 40 o/oo in both Aransas and Copano bays in August, 1951. Since these data were obtained, heavy rains have broken the drought, at least for the time being.

Salinity conditions in Louisiana waters can be expected to be less dependent on local climatic conditions, in view of the large area of the drainage systems.

TABLE 3

Monthly Average Salinities, Aransas Bay and Rockport, Texas (o/oo) *

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Aransas Bay												
1936	-----	-----	-----	-----	-----	17.4	7.4	17.0	18.1	17.0	13.8	20.4
1937	19.2	16.7	17.8	20.5	24.3	25.5	-----	-----	-----	-----	-----	-----
1938	29.4	21.4	19.8	20.8	7.4	12.9	25.0	28.8	23.0	25.5	23.8	24.7
1941	-----	-----	12.8	20.2	-----	6.4	21.0	27.1	28.0	18.7	19.9	19.0
1942	17.4	20.1	27.1	24.4	23.7	26.5	-----	22.9	-----	12.9	-----	-----
1946	-----	-----	-----	-----	-----	-----	-----	31.6	17.7	10.9	9.5	-----
1947	13.2	14.2	13.9	17.9	19.5	19.9	18.4	-----	24.0	22.0	22.8	-----
1948	21.8	27.5	23.1	29.9	27.6	33.2	31.9	36.8	-----	-----	-----	-----
Rockport												
1948	21.8	22.1	25.5	26.3	31.1	34.9	38.0	29.4	28.5	29.9	30.3	†
1949	30.4	28.5	26.4	24.8	20.6	25.1	26.7	28.5	30.6	23.9	24.3	22.5
1950	21.7	23.0	23.3	24.8	26.1	28.4	†	38.6	35.0	33.8	35.1	†
1951	34.0	32.7	33.7	33.7	34.2	†	39.2	40.1	36.2	32.1	31.4	30.2

* Data for Aransas Bay from Collier and Hedgpeth (1950), and Annual Report, G. F. O. C., 1949; For Rockport from U. S. Coast and Geodetic Survey records, courtesy the Director, U. S. C. & G. S.

† Data submitted by the Marine Laboratory at Rockport insufficient for satisfactory averages during the indicated months.

A recent trend towards a drier, more arid climate in South Texas has been suggested by Price and Gunter (1942). At some time in the immediate prehistoric era there was evidently a moister climate in South Texas, to judge from the oyster middens of Baffin Bay. According to Meyer (1942), the weather records of the last fifty years indicate a general trend toward increased evaporation over most of the United States, except the Rocky Mountains and the Great Plains. According to J. B. Leighly (personal communication) there is a perceptible downward trend of precipitation means in the last 100 years at both San Francisco and St. Louis suggesting a trend toward drier conditions. A general trend towards a warmer, milder climate in the Northern Hemisphere as a whole is indicated by the work of Ahlman (1949). Estuarine animals are hardy, and can be expected to lag behind such changes, although the drain upon their populations by man and his alterations of the environment may accelerate the decline of populations left behind by a change in climate. It would appear, for example, that the oyster beds of Port Isabel are a relict of better drainage conditions in the lower Rio Grande, which existed perhaps up to the beginning of intensive irrigation and its attendant diversion of river waters not much more than forty years ago.

B. Temperature

Temperature conditions are of more general importance in relation to the distribution of individual organisms and faunal complexes than are salinities. It is often stated, for example, that the richer estuarine fauna of tropical and subtropical regions is a result of the influence of higher temperatures upon osmoregulation (Panikkar, 1951). In the words of the Agriculture Department Year Book for 1941, the summer climate of coastal Louisiana is often "moist tropical," changing to hotter and drier conditions during periods of westerly to northerly winds. Average maximum temperatures for the coast range from 95 to 100° F., and average water temperatures in the harbors are from 87.1° F. at Galveston to 84.1° F. at Cedar Keys. The 84° surface isothere (Maximum isotherm) lies, according to Fuglister (1947), well out from shore in the Gulf of Mexico (Figure 15). The summer coastal

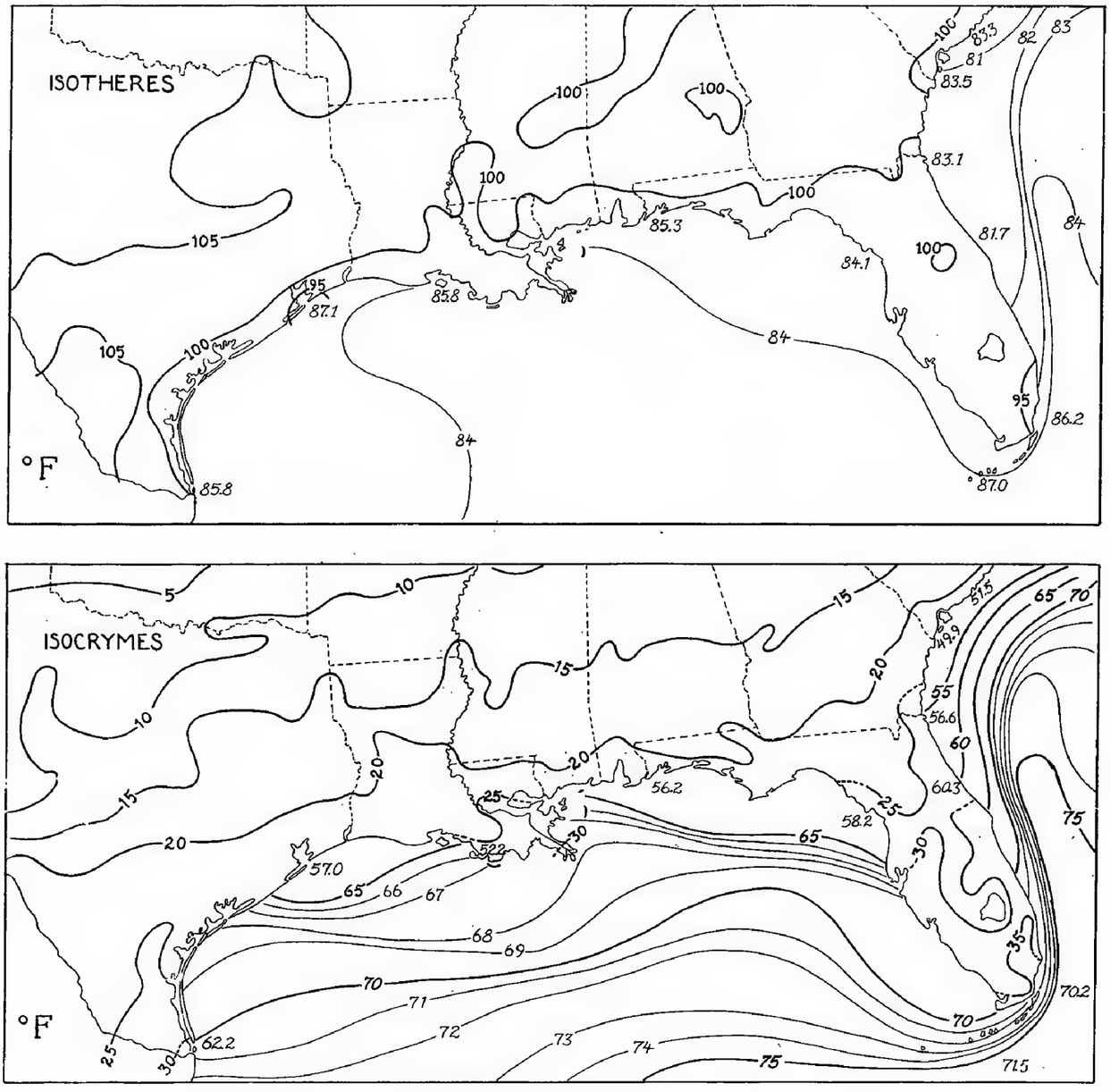

FIGURE 15

Above, average maximum; below, average minimum, temperatures, southeastern United States and northern Gulf of Mexico. Compiled from U. S. D. A. Yearbook, 1941, Fuglister (1947), and U. S. C. & G. S. water temperatures (1947). The shore localities indicated by the italics are the same as those in Figure 13.

temperatures of the Gulf of Mexico are higher than those of the south Atlantic coast, although the air temperatures are similar. There is thus a slightly greater differential between air and water temperatures along the south Atlantic coast between Hatteras and Daytona Beach along the northern Gulf coast. These differences are more pronounced during the autumn and winter months (MacDonald, 1938).

The pattern of minimum average temperatures (isocrymes) on land is more varied than that of the isotheres (Figure 15). While no part of the Gulf coast has escaped freezing temperatures, accompanied by local formation of thin ice in shallow bays, such extremes are very rare in southern Florida and in the vicinity of Port Isabel. The average minimum temperatures for the various harbor stations of the Coast and Geodetic Survey are somewhat higher on the Gulf coast than on the coasts of Georgia and the Carolinas, and although the water temperatures are as a rule higher on the Gulf coast, the extremes, when they do occur, have a pronounced effect on the fauna. This is a reflection of the higher summer temperatures, which permit the invasion of stenothermal, tropical or subtropical species into the shallow coastal waters, which suffer catastrophic mortalities during these severe drops in temperature. Gunter (1945a) has reviewed some of these incidents.

One of the most conspicuous aspects of the life of the bays and shallow waters of the Texas coast is the seasonal migration of many of the most abundant animals into the bays in spring and summer and back to the Gulf in autumn and winter (Gunter, 1945a, 1950b). Tropical strays entering those waters in summer are confronted with an unaccustomed variation in potential prey species as well as with the seasonal variations in the physical environment. As a result, they do not survive for very long.

Few data for the temperature of the offshore waters of the Gulf of Mexico are available, and most of these refer to the period of minimum surface temperatures. Phleger (1951) presents a series of diagrams of temperatures in the northwestern Gulf during January-March, 1947, indicating temperatures from 19° C to about 21° C at the top of the thermocline (75–125 meters). He found that the shallow water between 20 and 100 meters is colder and sharply different from the offshore water, and decreases shoreward to an average minimum of 14.5° C at the inner limit of observations a few miles from shore. Seasonal changes affect only the upper water layer above approximately 75–125 meters. The thermocline below this depth extends to 800–1000 meters, and below this depth the temperature is approximately 5° C.

Hutchins (1947) has divided the distribution of coastal marine organisms in the Northern Hemisphere into four distinct types, on the basis of average maximum and minimum temperatures. Two of his zonal types, 2 and 4, limited in their southern extension by the 70° F. isocryme, occur in the Gulf of Mexico, with their northern limits at Cape Cod and Cape Hatteras, respectively. Both of these zones skip southern Florida and it is possible to assign some of the common invertebrates of the northern Gulf coast to these two zones (see Part IV of this work).

Hutchins' zonal types 2 and 4 correspond roughly with the temperate and subtropical zones proposed by Vaughan (1940) on the basis of temperature extremes. The tropical zone of Vaughan, with a temperature range between 77 and 86° F., is approximated by Key West, although the minimum in that locality may sometimes fall to the high 50's. If Vaughan's scheme were to be followed strictly, Key West

would fall in the subtropical zone with its range of 59.0– to 86.0–91.4° F. The lowest monthly average recorded for Key West is 65.8° F. However, the records of Key West cannot be taken as characteristic of the reef tract as a whole, and such extremes should not be accepted as the limits of a zone. The tropical character of Florida has been re-emphasized by the recent studies of the Stephensons (1950). There are then, three overlapping zonal patterns in the Gulf of Mexico: a mid- or low-temperate zone, a subtropical zone, and the tropical zone (Figure 16).

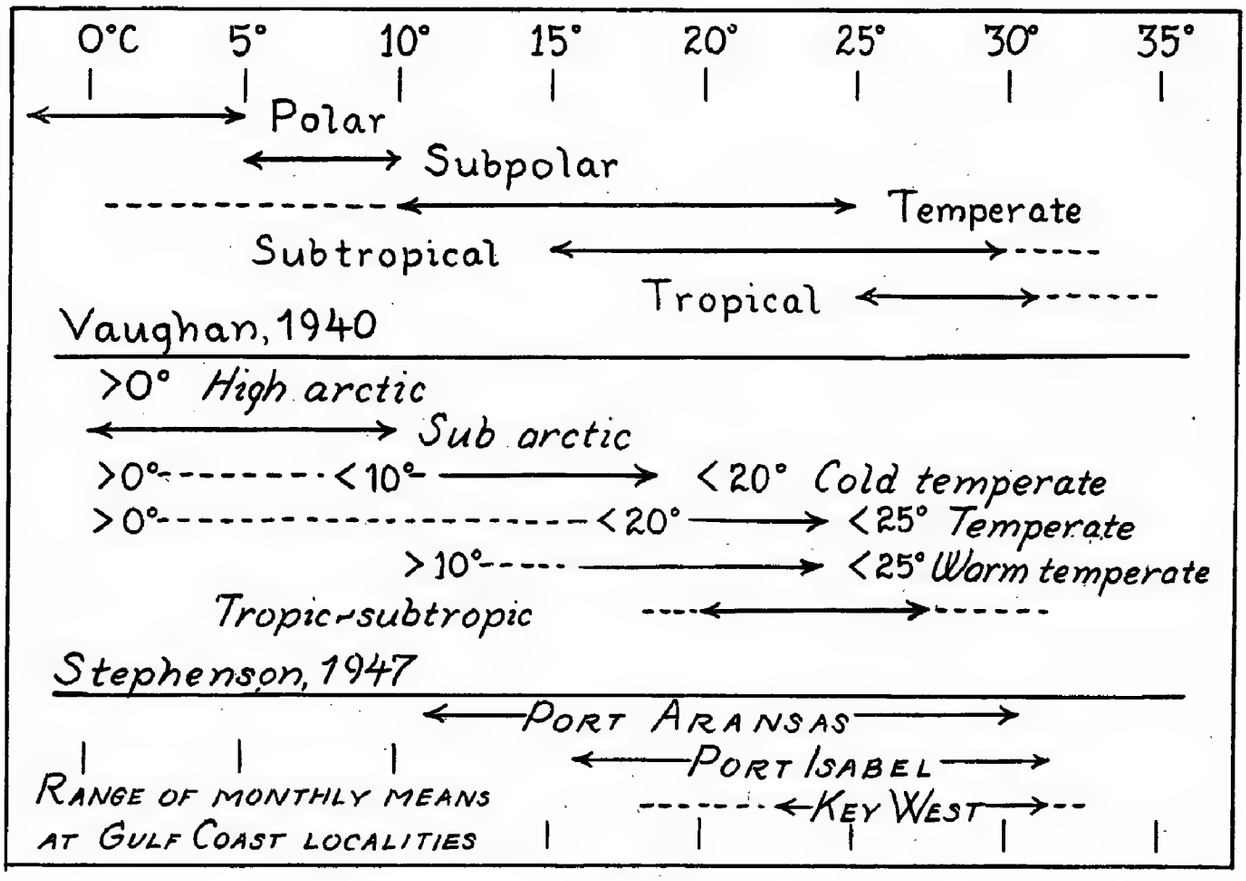

FIGURE 16

Diagram showing temperature zones according to the schemes of Vaughan (1940) and Stephenson (1947), together with the annual ranges at Port Aransas, Port Isabel, and Key West on the Gulf Coast.

C. The Hydrographic Climate

1. General Considerations

A number of attempts have been made to classify marine environments by temperature characteristics or by the salt content of the waters, but there seems to have been no serious effort to combine these factors to express what may best be termed the "hydrographic climate" (Hedgpeth, 1951). It is difficult to apply this method as a means of general comparison because the necessary data are wanting. For the coasts of North America, however, a useful series of such data has been gathered by the U. S. Coast and Geodetic Survey since 1922 at their tide gauging stations (U. S. C. & G. S. 1947, 1949). The method of presenting these data in graphic form is illustrated in Figure 17, showing the means and extremes for the tide gauging station at Galveston.

Because of the manner in which these readings are made, they cannot be considered accurate averages for the general vicinity, but they do provide a useful indication of the temperature and salinity conditions. If a number of localities are represented on

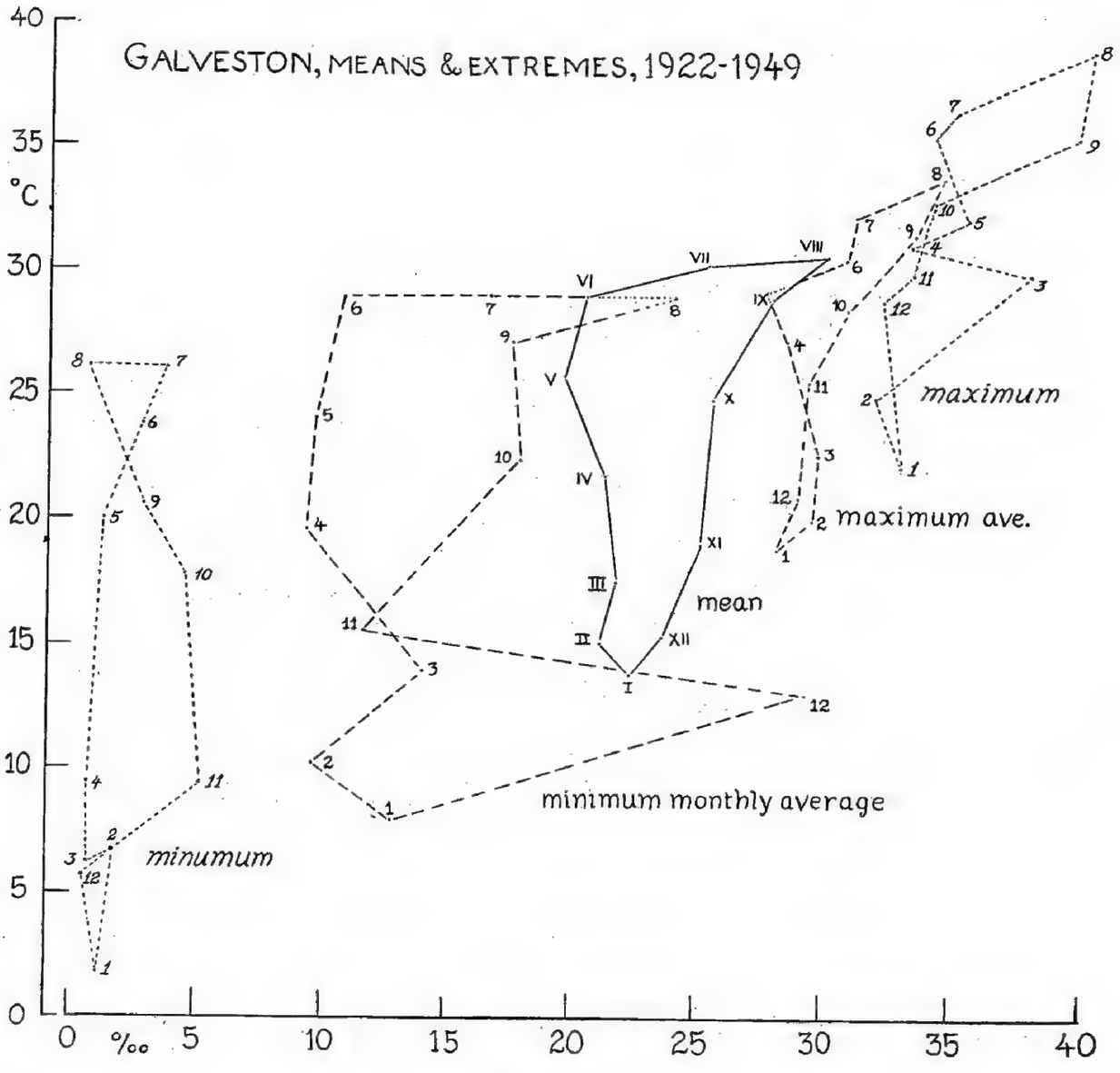

FIGURE 17

The hydrographic climate at Galveston, showing ranges of means and extremes for the indicated period. From U. S. C. & G. S. data (1947, 1949).

the same graph, the relationships between localities which have common faunal elements are clearly suggested (Figure 18). For example, this figure suggests that euryhaline organisms occurring at Key West and Woods Hole could live at Galveston, at least in the appropriate seasons, and that there should be little in common between the fauna of Key West and Woods Hole because of the narrow overlap of the polygons.

An examination of the polygons for Key West (Figure 19) suggests a more plausible explanation for the distribution of disjunct species than the wholesale lowering of averages hypothesized by Deevey (1950). Deevey did not consider the possibility that comparatively slight changes in the average water temperatures would in-

crease the frequency of lower means in the late interglacial periods similar to the present, when average temperatures at Key West are tropical nine months of the year, but for the three winter months, December, January and February, are occasionally low enough to permit temperate organisms to live. For long periods, historically speaking, temperatures were probably cool enough, during the periods of transition between glacial and interglacial periods, to permit migrations between the Gulf and Atlantic, even without the submergence of Florida. This would require a lowering of averages at Key West by 1.5° or 2° C.

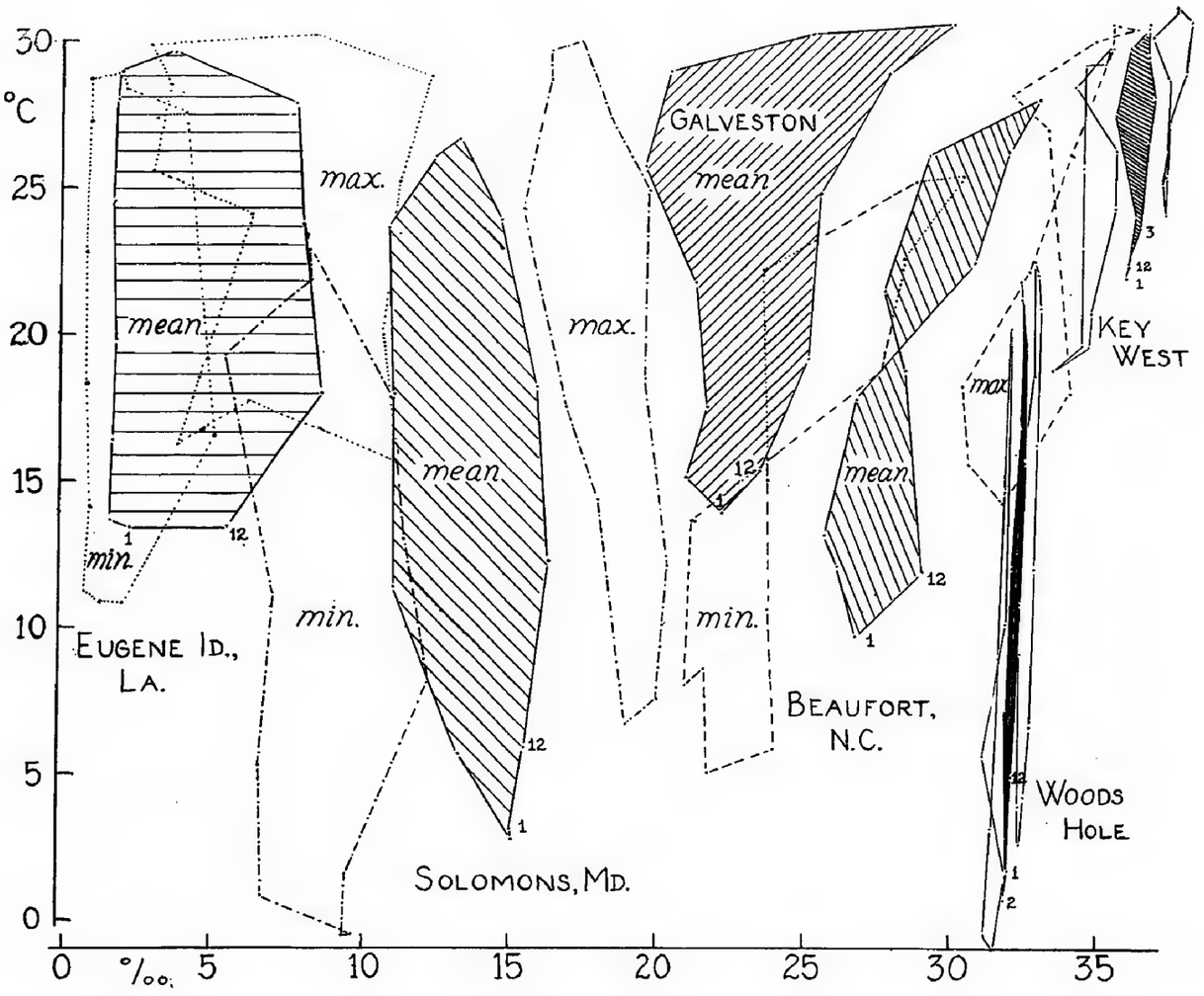

FIGURE 18

Graphs of "hydrographic climates" for various Atlantic and Gulf Coast localities. The points are monthly means, proceeding in a clockwise direction from 1 (January) to 12 (December). Compiled from U. S. C. & G. S. data (1947, 1949).

In Figure 20 the hydrographic climates of several localities on the Texas coast and one near the outlet of the Atchafalaya River in Louisiana have been plotted. This indicates the extraordinarily broad range of environmental conditions to be found on the Gulf Coast. This range, however, is principally in the salt content of the waters; the temperature characteristics are approximately the same. These temperature characteristics overlap Vaughan's (1940) subtropical and temperate zones. As Hutchins (1947) has demonstrated, zonal distribution is best represented in its seasonal and spatial aspects. Vaughan's system, however, does provide us with convenient definitions for the widely used terms, "tropical," "subtropical," etc. (See Figure 16).

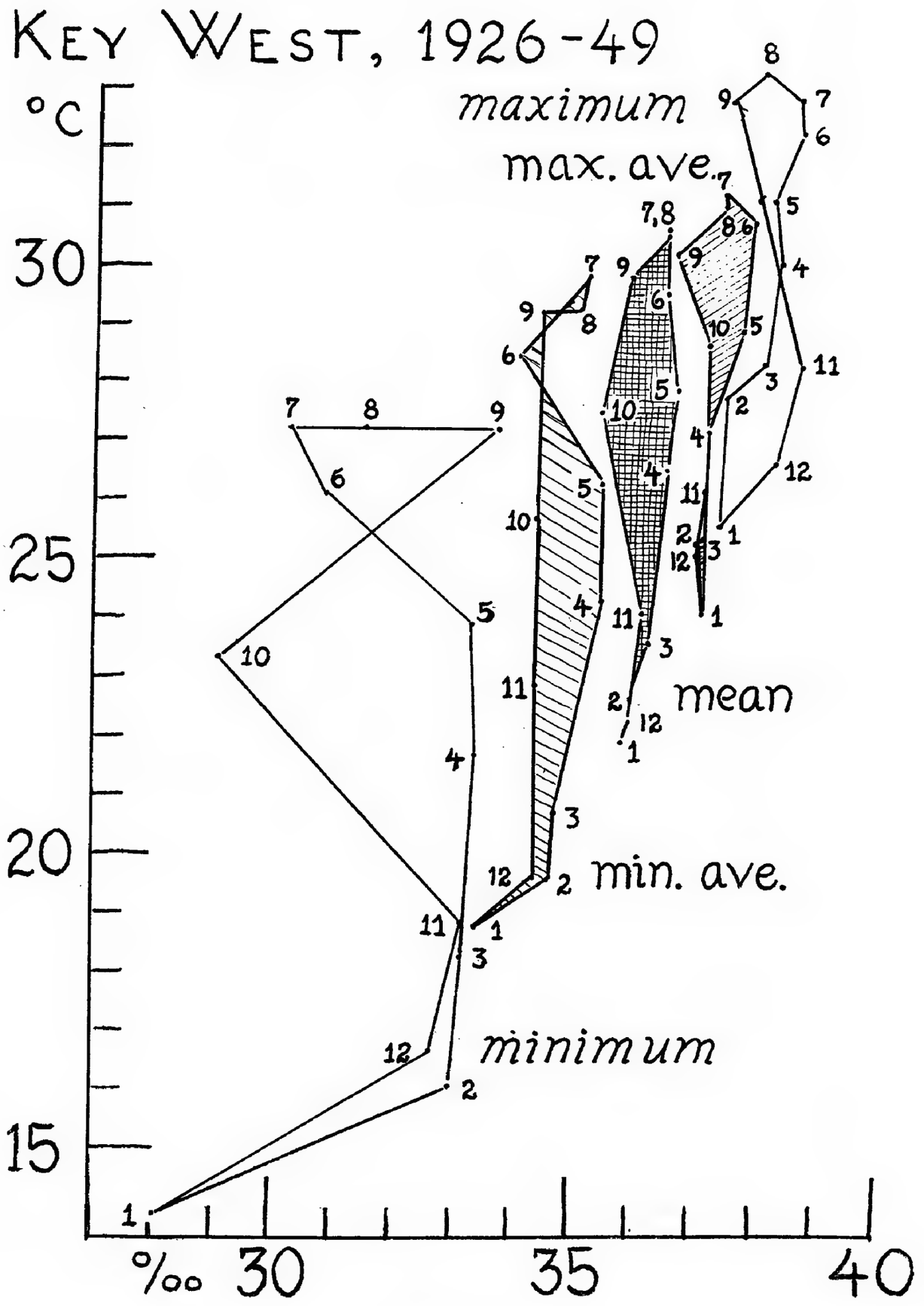

FIGURE 19

The hydrographic climate at Key West, showing ranges of means and extremes for the indicated period. From U. S. C. & G. S. data (1947, 1949).

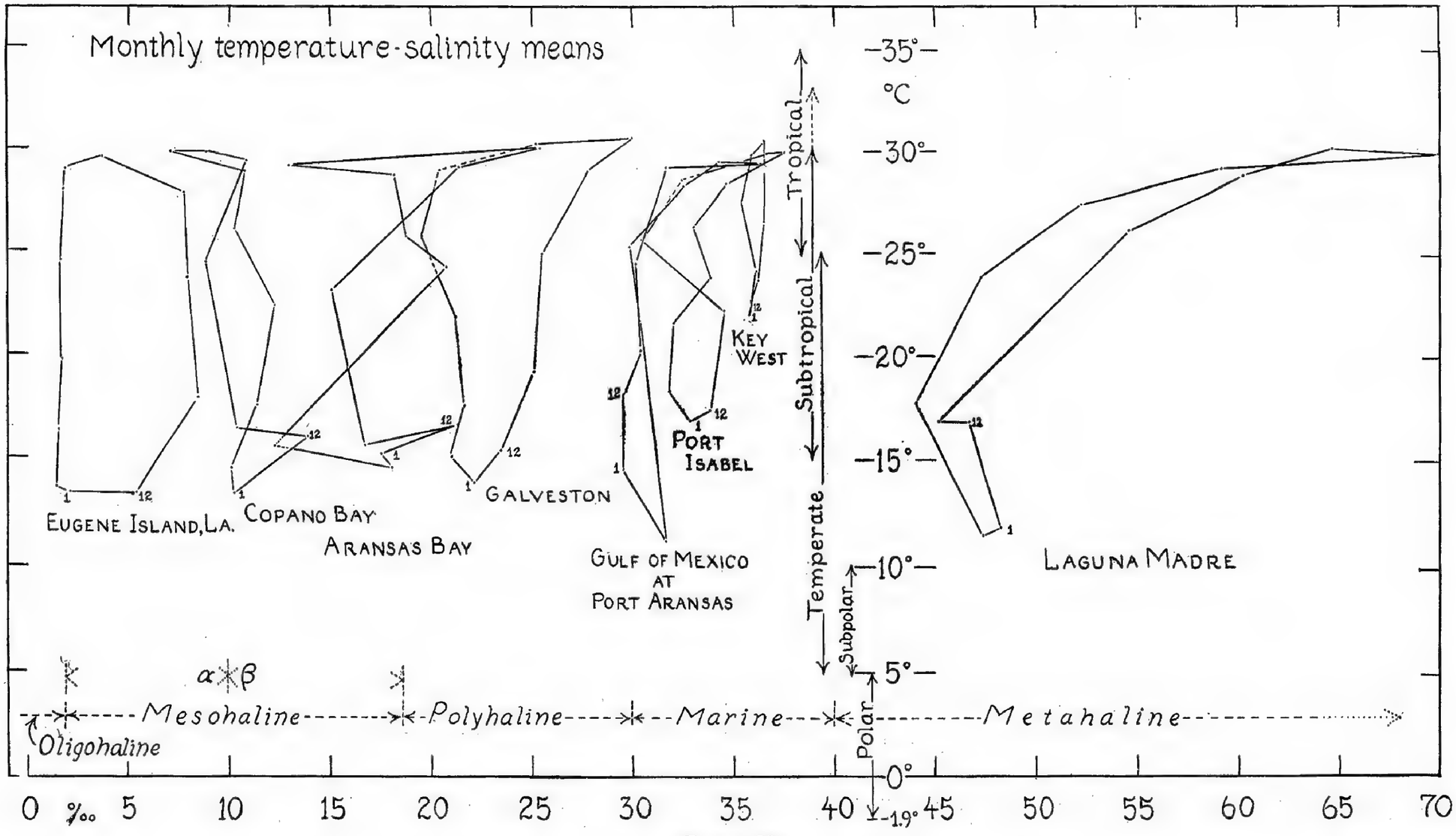

FIGURE 20

Mean hydrographic climates for various stations and areas on the Gulf Coast, together with Vaughan's system of temperature zonation and Redeke's salinity spectrum classification. Compiled from various sources.

Turning to the salt content of these waters, a surprising range, from nearly fresh water to a peculiar, hypersaline condition, is exhibited. The well known classification of Redeke (1922), based principally on the studies of brackish water life in northern Europe, is indicated on Figure 20. The limit of the oligohaline region is roughly 1.8 o/oo, the mesohaline, or brackish water "par excellence" (Redeke, 1933) lies between 1.8 and 18.5 o/oo. From 18.5 o/oo to 30 o/oo is the polyhaline zone, a region of lessened salinity conditions commonly invaded by marine organisms. The true marine environment is that between 30 and 40 o/oo. Beyond this is the environment not included in Redeke's system, to which it was suggested that the term "metahaline" be applied (Hedgpeth, 1951). It should be pointed out that Redeke's system was originally based on the chloride content of the waters rather than on the total salinity, but for various reasons, salinity is now used. The mesohaline zone is further divided into alpha and beta regions; this break seems to coincide with the lower limit of optimum oyster populations in our waters. The upper limit of the oyster optimum, however, lies somewhere in the polyhaline zone. Other European workers have proposed modifications of Redeke's system and further schemes of terminology; these have been summarized by Rottgardt (1952) in a diagram (Figure 21). It is apparent that even in a relatively small part of the world, there is little agreement. As Petit and Schachter (1950) remark, these classifications vary with the local conditions known to the classifier, and they mention a classification by Brunelli for conditions on the Mediterranean coast and lagoons of Italy. According to this scheme, oligohaline

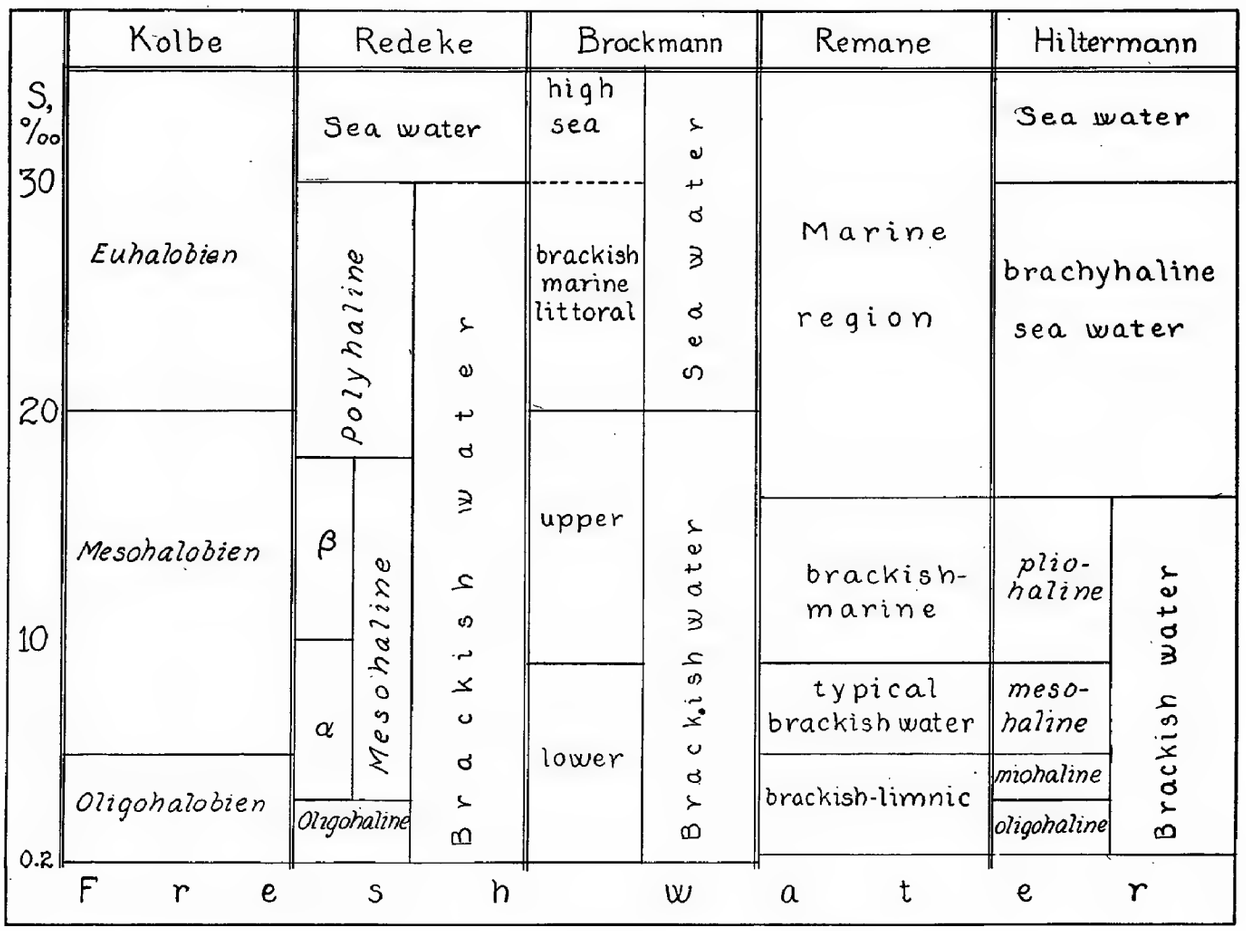

FIGURE 21

Schemes of classification of brackish waters proposed by various workers. After Rottgardt (1951).

is from about 0 to 9 o/oo, mesohaline from 9 to 18, polyhaline from 18 to 36, and marine (isohaline) from 36 to 38 o/oo. The lagoonal environment, over 38 o/oo, is termed "hyperhaline."

As with all such classifications, the boundaries should be considered as "gray zones" of transition rather than sharp limits. The most conspicuous phenomenon in such a transition is the increased gradient. The polygons for Galveston and Aransas Bay are broad, indicating a regularly wide range of salinity conditions; that for the Gulf at Port Aransas (which represents average temperature and salinity conditions encountered at a number of stations within five miles of Aransas Pass in the Gulf of Mexico), shows a much narrower range of variation. The boundary therefore, is not a hard and fast limit at 30 o/oo, but a range between 25 and 30 o/oo.

An indication of the range of environmental conditions which may be smothered under a representation of averages alone is indicated in the figure for Galveston and Key West. The limitations of these data which have been discussed above must be reiterated in connection with the graph for Galveston in particular; undoubtedly these conditions do not obtain for the whole region in the vicinity of Galveston, and some of the extremes indicated have occurred only a few times during the 28 years of observations, and were of short duration. Cold spells are occasionally severe enough, however, to cause mortality to fish and some invertebrates. This indicates that temperature extremes of several days duration, although masked by averages, must be considered in an appraisal of the environment. According to Gunter (1947b), who has searched the literature for records of mass mortality following hard cold spells in the Texas coast, such episodes occur "about every six to fourteen years or approximately every ten years." The most recent occurrences were in January, 1947, and January-February, 1951 (Gunter and Hildebrand, 1951). Whether these cold spells are actually increasing in frequency or are simply being more adequately reported in recent years is difficult to determine. It is possible, with the apparent trend toward a warmer, drier climate in South Texas, that the range of environmental extremes is increasing, so that winter extremes occur more frequently. This might be a temporary, unstable condition, to be followed by a generally warmer climatic type in the future. Certainly the environmental extremes at the present time are more severe on the Texas coast than farther east.

2. The Bays and Estuaries

The complex of bays, estuaries and inlets of the Texas and Louisiana coasts presents a wide range of environmental conditions, from shallow, lake-like bays to narrow sluggish bayous and channels which are 30 feet deep in a few places, with bottoms varying from hard sand to very soft mud, and all conceivable combinations of sand and mud. The larger bays are somewhat oval in shape, with shallow inshore areas of varying width, separated from the generally flat bottom of the basin by an abrupt slope (Figure 22). Salinities vary from nearly fresh water to oceanic concentrations, and temperatures from near freezing in winter to highs in excess of 31° C. in summer.

If these tidal waters have one feature in common, it is their variability, both seasonally and from year to year. Such variation is characteristic of estuaries, but it is extreme on the northern Gulf coast, where floods may change the salinity of a fairly large bay from 15 o/oo to nearly fresh water in a few days, or periods of drought, accompanied by high temperatures, may raise salinities to hypersaline concentrations.

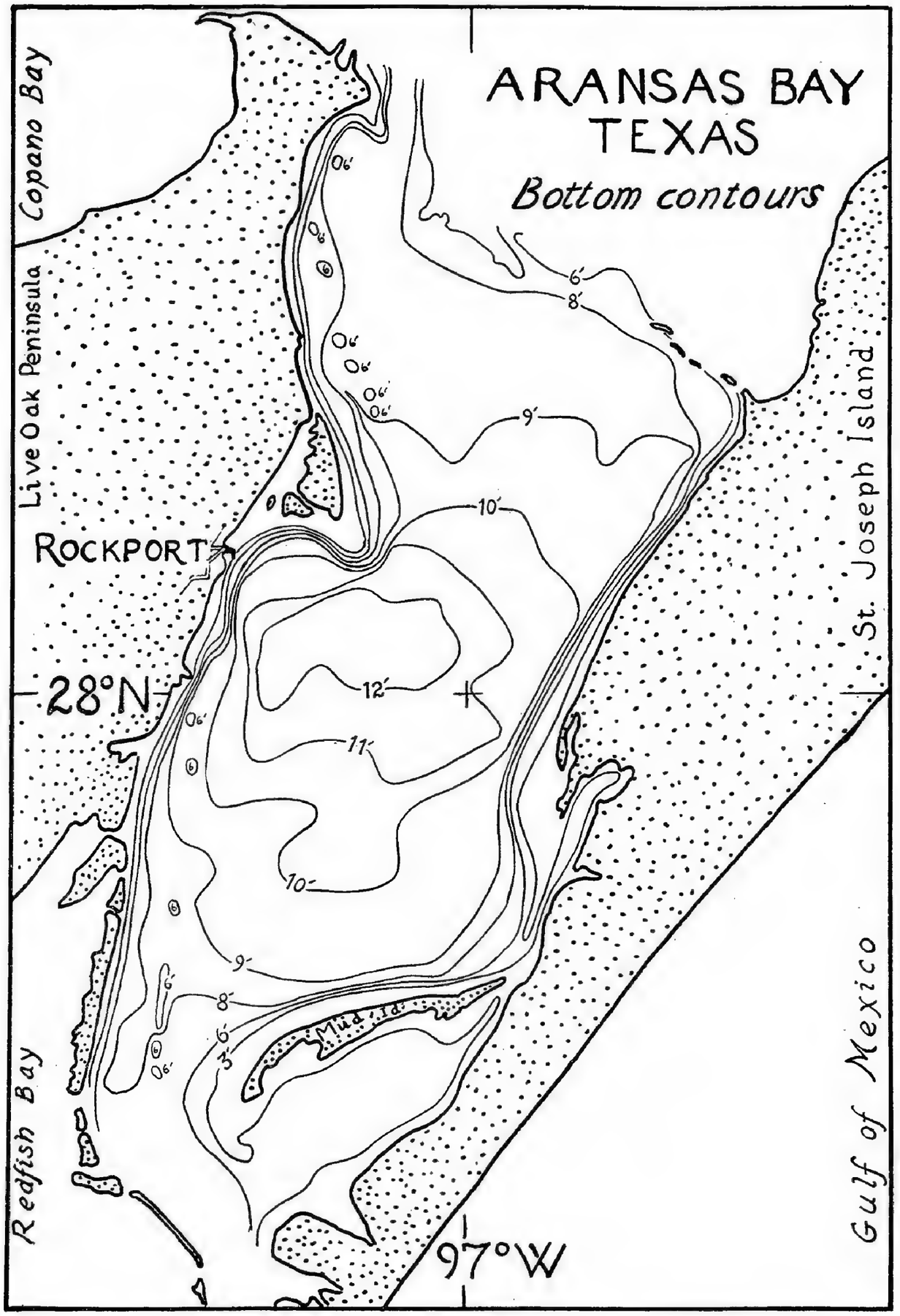

FIGURE 22

Bathymetric map of Aransas Bay, Texas, showing narrow inshore shelf, slope, and basin topography characteristic of Texas bays. (From Collier and Hedgpeth, 1950.)

Louisiana waters are more subject to dilutions, and Texas waters, especially from Matagorda Bay south, to concentrations. As yet there is no long term series of observations for any bay system; the nearest approximation to such a series is that for Copano and Aransas bays, and there are many gaps in this series (Collier and Hedgpeth, 1950). Each system of bays, from the head of tidewater to the Gulf of Mexico, is a separate hydrographic economy, which must be studied in detail to be understood. The hydrographic regime of such waters is the reflection of a complicated series of interactions between river drainages, climatic factors, and tides.

The records of various years indicate that conditions have been extreme during the past several years, especially from 1948 through 1951, in Aransas Bay. Precipitation has been below average, and during 1950 the mean air temperature was higher than normal for every month. The result has been an increase in salinity, at times approaching 40 o/oo, in Aransas Bay at Rockport (Figure 23). Even in normal years

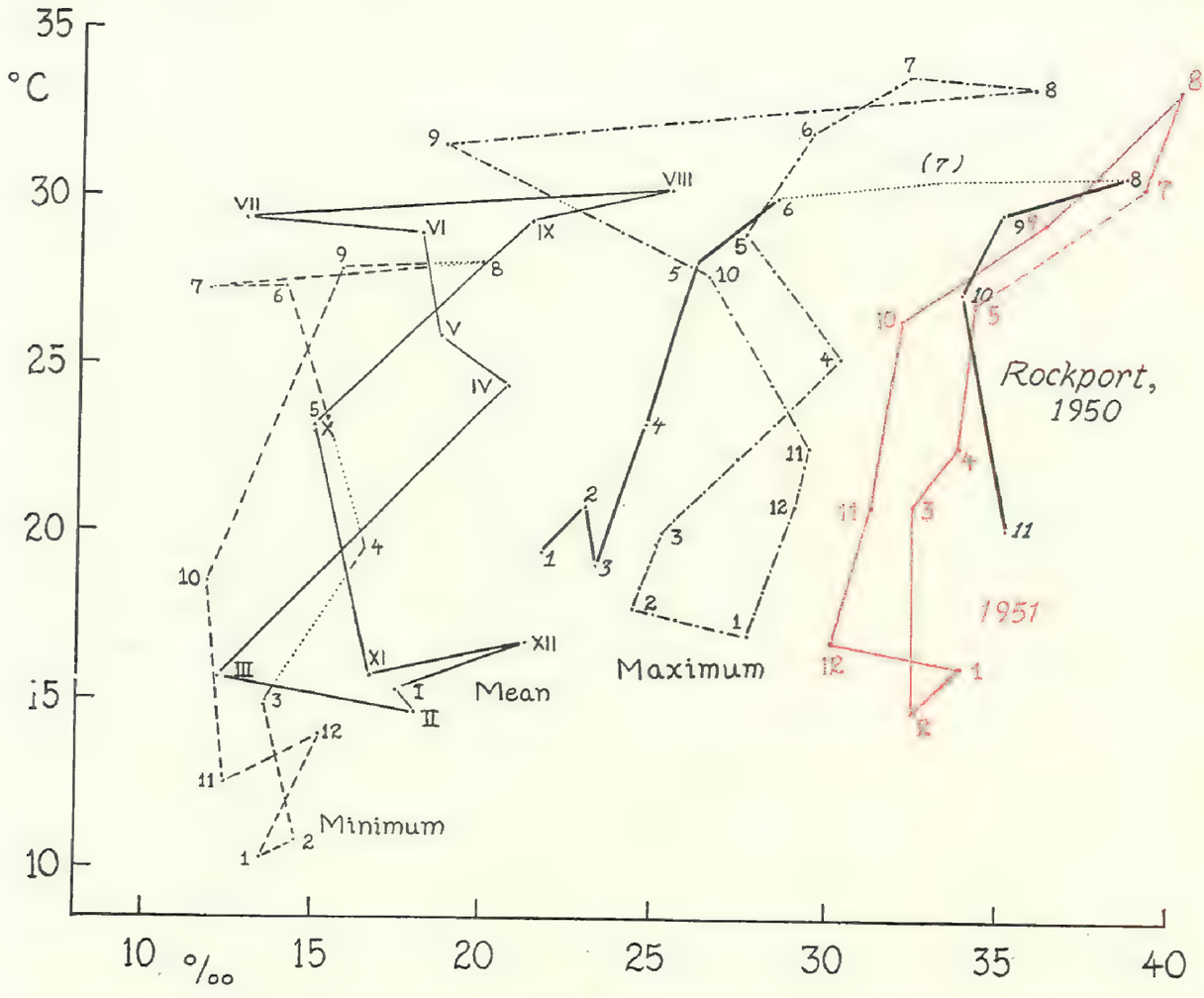

FIGURE 23

Maximum, minimum, and mean averages for temperature and salinity, Aransas Bay, and for 1950–51 at Rockport. Data for July and December were unfortunately not obtained by the Marine Laboratory at Rockport in 1950.

the higher average salinity in lower Aransas Bay is probably one of the reasons for the absence of oyster reefs in that part of the bay, and during such drought periods as that recently experienced, many marine organisms move into the bays. Squid, for example, were taken in Copano Bay in 1950.

In view of the paucity of comparable data for other parts of the northern Gulf coast, it cannot be said that the regime of the Aransas Hydrographic system is typical, but somewhat similar situations are to be expected in other regions. At the extremes, however, conditions are markedly different. South of Corpus Christi, in the Laguna Madre, salinities are usually higher than sea water, and in Louisiana the vast volumes of fresh water from the Mississippi lower salinities to such a degree that in a few localities, *e.g.*, south of Marsh Island, the salinities in the Gulf of Mexico itself are low enough to permit the development of oyster reefs (Figure 24).

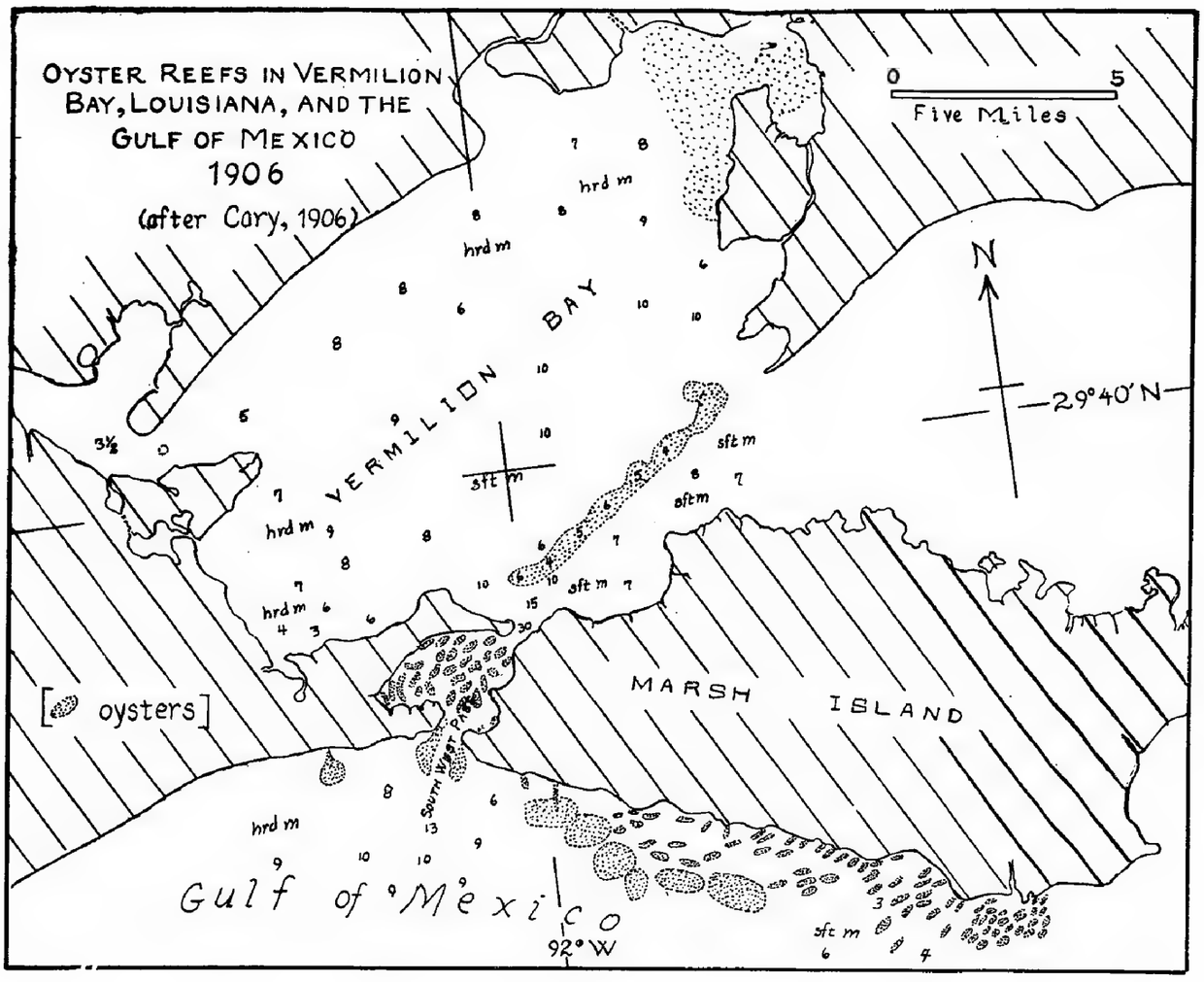

FIGURE 24

Oyster reefs in the Gulf of Mexico south of Marsh Island on the Louisiana coast, according to a survey made in 1906. Recent examinations of this locality indicate that there has been no substantial change in this area. (After Cary, 1906a.)

In areas subject to high salinities as the result of inadequate stream drainage and high temperatures during the summer, as in the Laguna Madre, mass mortalities of fish have been recorded (Gunter, 1947b). In some years floods have wiped out living oysters in the inner bays; such mortality was observed in Nueces Bay in 1935 following the greatest flood on record of the Nueces River, and episodes of this character are common in Louisiana. The major cause of oyster mortality observed in recent years seems to be the gradual loss of fresh water to the bays, as a result of the alteration of drainage patterns by reclamation projects or agricultural diversions outside the coastal region, or from natural causes (diseases?). The increase in salinity permits

such predators as *Thais* to invade bays, and possibly favors the spread of such enemies as the fungus *Dermocystidium* (Mackin *et al.*, 1951).

With one exception, at least so far as observed, the bays of the northern Gulf coast are sufficiently exposed to tidal action, or lack the other conditions that promote an excess production or concentration of phytoplankton (see note 4, below) which is accompanied by mass mortality of fish and larger invertebrates. The exception is Offats Bayou, near Galveston, where summer mortalities are almost annual in occurrence. Gunter (1942) considered these mortalities to be a result of anaerobic decomposition in an enclosed, stagnant body of water. Recently Connell and Cross (1950) discovered large numbers of a species of *Gonyaulax* in Offats Bayou and attributed the mortalities to the blooming of this dinoflagellate.[4]

The variations, especially in salinity, which prevail in the bays and estuaries of Texas and Louisiana, forbid the application of neat schemes of classification to the water types. Such classifications may indeed imply distinctions which do not exist. It is necessary there to emphasize the differences between environments which fluctuate in response to seasonal differences in run-off and tidal variations (estuaries), and environments whose stability supports a similarly stable terminology (brackish waters).

Estuarine waters are usually thought of as being sub-oceanic in their salinity characteristics, but waters of supra-oceanic concentration have faunal characteristics in common with estuaries, and their hydrographic characteristics are in some ways a mirror inversion of conventional estuaries. That is, the inflowing water from the sea is of lower salinity than that of the lagoon, and the exchange pattern is hence the reverse of that in a low salinity bay where the inflowing water is of greater density and enters below instead of above the water already in the estuary. It is therefore possible to construct a model or diagram which satisfies the conditions of both types of salinity exchange, depending on whether it is erect or inverted.[5]

The differences in the fauna, especially in the distribution of sedentary pelecypods, are more reliable indices of the "normal" conditions found in the various bays. Thus we may speak of "Rangia waters" and "oyster waters," strictly in reference to the local conditions. In a study of foraminifera and mollusk collections from San Antonio and Aransas bays and the adjacent Gulf, Ladd (1951) (also see Post, 1951) recognized several natural divisions or "facies" related to the salinity gradient. In this scheme, the lower bay environment is indicated by a "polyhaline facies," while the others are given names indicating their geographic location. A somewhat similar sub-

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[4] It is not certain, from the account of the 1950 outbreak, that the dinoflagellate bloom was the cause of this episode. See the comments of Gunter, and of Hedgpeth in Science, 113: 250–251 (1951). Specimens recently collected from Offats Bayou are considered identical with *Gonyaulax monilata.*

[5] The study of estuaries is fashionable these days; in addition to the publication of symposia and review papers, there are extensive programs of estuarine investigations in various parts of the world. The results of two of these, apparently concurrent but completely independent, are now being published (Rochford, 1951a; Day, 1951). Rochford's analysis of the cycle of interstitial phosphate of the bottom sediments is of particular interest. In a later paper (1951b) he has discussed the significance of this cycle to oyster culture, describing experiments involving the application of superphosphate in linseed oil meal to the bottom with a resulting increase of growth rate in oysters. It is possible that a similar regime is the order of events in Texas bays, which are not noticeably rich in phytoplankton. The role of mud-grubbing fish (*e.g., Dorosoma* and *Mugil*) in utilizing organic material in the mud and thus playing an active part in the cycle is discussed by Gneri and Angelescu (1951).

division, based on the distribution of foraminifera, has been recognized by Parker, Phleger and Peirson (1953).

The field work for Ladd's study was done in 1940; the several preceding years were characterized by heavier rainfalls and lower bay salinities than those which prevailed since 1948. A classification based on the distribution of *motile* organisms in Aransas Bay during 1948–51 would result in characterizing the lower bay as "marine" and Copano Bay as "polyhaline," although the assemblage of bivalves, on which some future paleontologist would have to depend for his reconstruction of conditions, would indicate a transition from near fresh water conditions in upper Copano Bay, as Ladd has suggested in his term "bay head facies." This variable character of the environment can be indicated by the use of the term "estuarine" to cover the range between fresh water and the sea, or by superimposing the curve of approximate number of species upon Ladd's facies map and indicating that in high salinity years the whole curve shifts to the left (Figure 25). Gunter (1947a) has discussed the implication of modern faunal assemblages for the interpretation of past gradients; in addition to the obvious reduction in number of species of marine-derived character with the decrease in salinity there is also a reduction in average size of the species whose ranges transgress the salinity gradient. However, this is not always a clear cut relationship, as Zernov (1949) has pointed out for some mollusks in various parts of the Baltic.

D. Currents

The inshore currents of the Gulf of Mexico have not been studied in adequate detail. It can be inferred, from such studies as those of Bullard (1942) on the distribution of river sands along the Texas coast and Geyer's (1950) summary of salinity conditions west of the Delta, that the prevailing set of inner coastal currents is westward and southward, or counterclockwise, in the northwestern part of the Gulf at least to Big Shell on Padre Island, where there seems to be a convergence with a northward current along the shore. Further evidence for this inference is the structure of the tidal delta at Pass Cavallo and the accumulation of sand on the south side of jettied passes together with the indication of removal from the north side.

If the currents of the Gulf of Mexico as a whole are summarized by quarters, seasonal differences are apparent (Figure 26). These are most pronounced in the northeastern part. As can be seen from this figure (which omits surface currents of less than about 5 miles a day, and consequently the smaller eddy systems), the currents a few miles off the Texas coast set northward during the summer quarter, and this northward set is evident also in the spring quarter. Pronounced differences in surface and bottom currents in shallow water near shore are experienced by commercial trawlers; at some times, especially during the summer months, the reverse directions of surface and bottom currents make trawling difficult.

With respect to the current system of the Caribbean and western Atlantic as a whole, the currents of the Gulf of Mexico, exclusive of the main system of the Florida Current, comprise an eddy. This is accompanied by the stranding of various large seeds, from plants growing in the Caribbean, along the northern shores of the Gulf of Mexico. Only one of these, the black mangrove, *Avicennia nitida*, has successfully colonized the region west of the Delta, where it is a conspicuous element in the flora of the lower marshes as far west as Cote Blanche Bay. Guppy (1917) suggested that this plant originally came from Africa, the seeds drifting across to the New World, and thence to

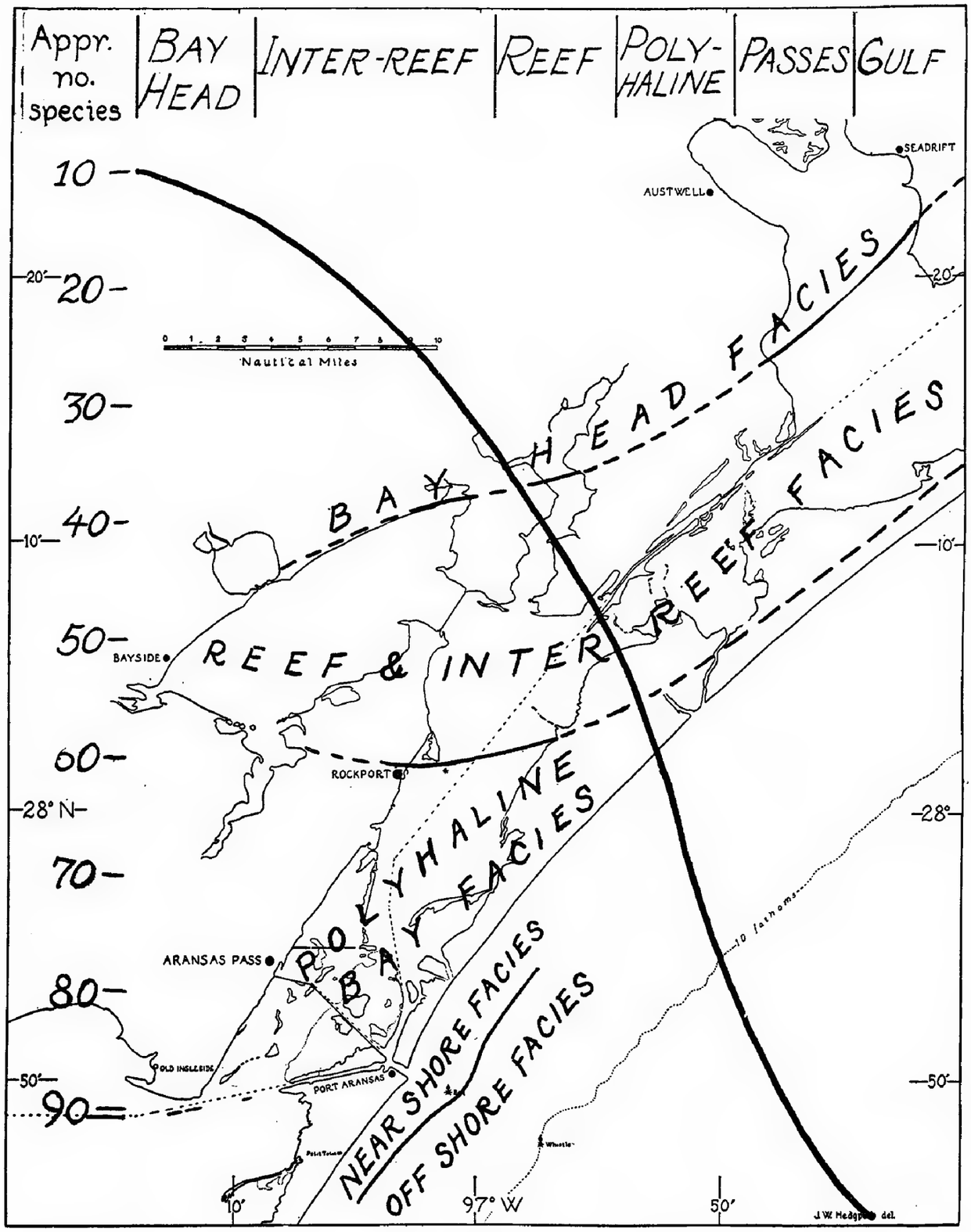

FIGURE 25

Molluscan-foraminiferan facies on central Texas coast, according to Ladd (1951), with superimposed curve indicating approximate number of species. As a result of a series of dry years, the curve has moved to the left.

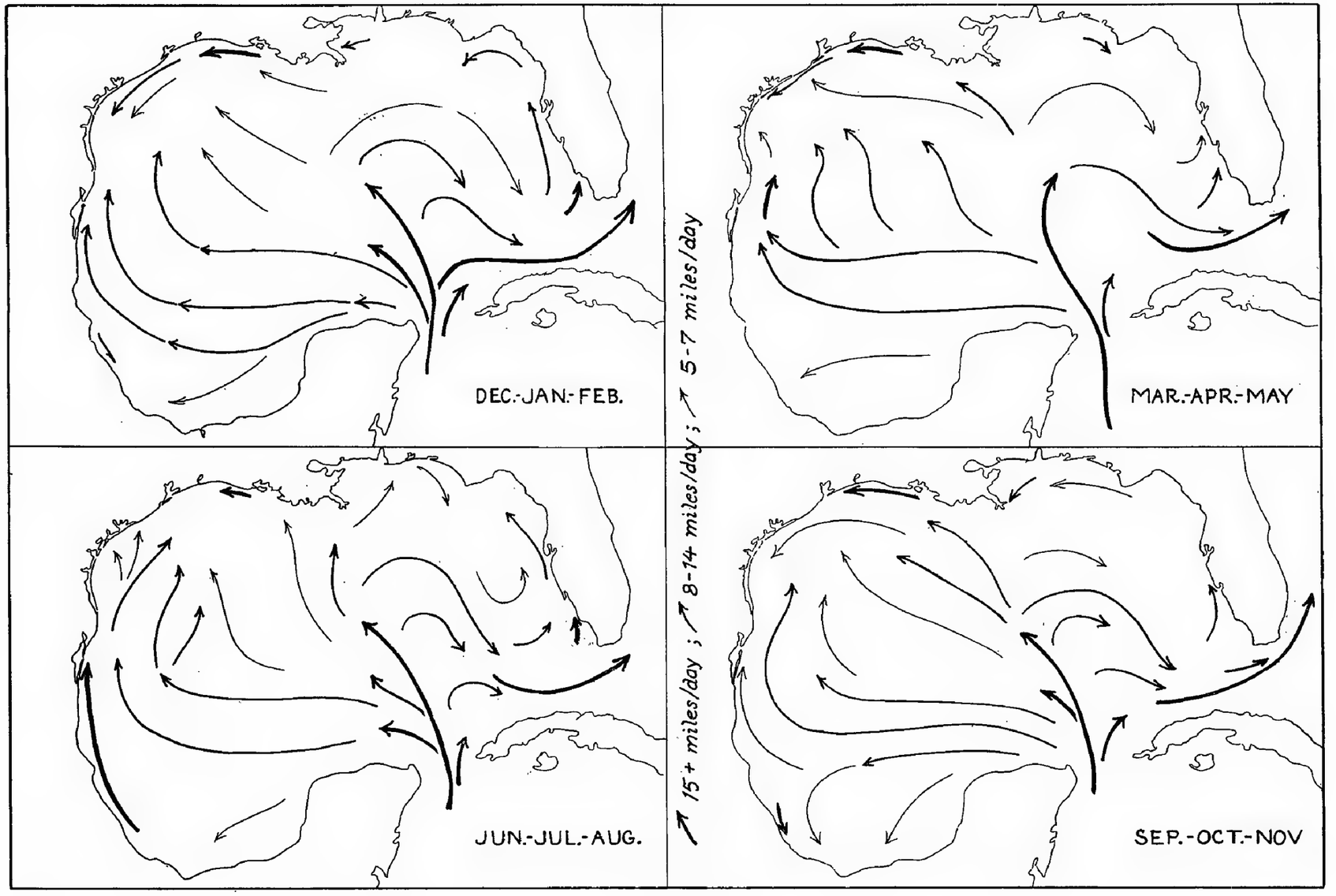

FIGURE 26

Surface current patterns in the Gulf of Mexico by quarters. Streamlined freehand from Current Charts, Central American waters, U. S. H. O. Misc. 10,690, 1–12.

Bermuda. Sprouting seeds of this plant are cast ashore along the Texas coast, but the beach is too dry and sandy for them to take root. There may be an occasional plant on a bay shore, but dense thickets of black mangrove are unknown on the Texas coast. In Louisiana the plant grows near the limits of its tolerance, and in some years suffers from frost.

Several other conspicuous seeds are commonly found in beach flotsam, the "sea beans" of popular terminology. The largest of these is the dark red, kidney shaped bean of *Entada scandens*, which is found on beaches from the West Indies to Norway. Seventeenth century naturalists thought these beans were the "seeds" of Alcyonarians; more romantic people thought them to be the hardened kidneys of some supernatural creature and wore them as charms or made them into snuff boxes. Guppy proposed "Gulf nut" as a more suitable name for this seed. The plant grows in Jamaica. A smaller bean, more regular in shape, is that of *Mucuna*, a widespread tropical genus. There may be several species of these attractive beans, which range in color from dark reddish brown to pale brown, encircled by a conspicuous black band (the umbilicus). Another widespread seed often found on Texas shores is that of *Guilandina bonducella*, which grows in the West Indies and on the Caribbean mainland near Cartagena.

The current patterns of figure 26 represent the surface current velocities for each three month period in the area indicated and should not be considered as indicative of the actual transport of water masses in the Gulf of Mexico. Adequate understanding of this problem awaits intensive hydrographic surveys. At the present time, only the old temperature readings of the *Blake* and the data from the brief cruise of the *Mabel Taylor* in 1932 are generally available. In discussing this latter series of data, Parr (1935) concluded that there was "no actual transportation of surface water from the Caribbean Current into the Gulf of Mexico during the winter of 1932." He also found little evidence of the contribution of Gulf waters to the Florida Current, and made the "tentative conclusion" that "the water masses of the Gulf of Mexico proper should be considered part of the coastal water system of the North and Central American Atlantic seaboard and not as a part of the oceanic circulation system of the Caribbean and Florida Currents. Probably the exchange between the Gulf of Mexico and the neighboring coastal waters is relatively very slight and slow, but it seems indicated that whatever residual tendency to move in any one direction there may be, will be chiefly in the direction opposite to that of the Caribbean and Florida Current." (p. 73).

Commenting on the traditional presentation of current charts, which show no water outflow from the Gulf, Leipper (1951) says, "This situation cannot exist unless there is a submarine return current of equal magnitude, which is unlikely."

E. Tides and Sea Level

In the Gulf of Mexico tidal action is damped and the range of the tide reduced to from 2 to 3.5 feet. The small tidal ranges exert effects out of proportion to their magnitude, especially on a seasonal basis. The seasonal variations in sea level cause proportionately large changes in the volumes and surface areas of the shallow bays, and the tidal currents in the narrow inlets affect the migrations of organisms through the passes. The seasonal changes in sea level are for the most part coincident with an in-

crease in tidal heights during the equinoxes; the highest sea levels occur during September and October, and the secondary high levels during March and April. The seasonal levels at Galveston, for which we have the best record, also coincide inversely with the average barometric pressure over the Gulf of Mexico (Figure 27), but this does not necessarily mean that the two are correlated with each other, but that both are probably reflections of the seasonal changes in the North Atlantic wind system.

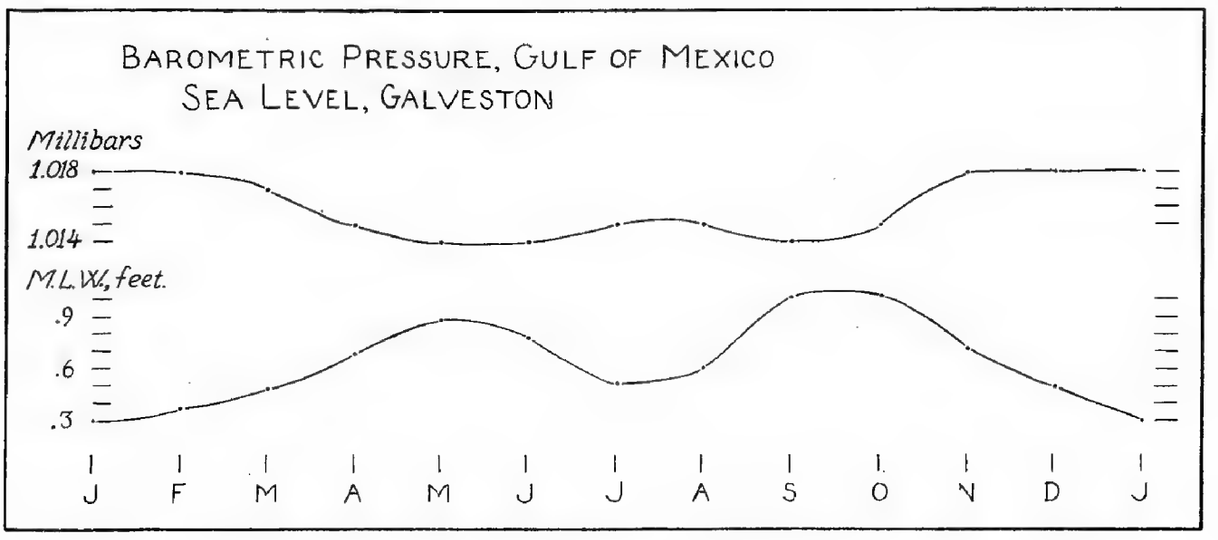

FIGURE 27

Monthly mean barometric pressure over the Gulf of Mexico, and sea level at Galveston. Pressure data averaged from isobars of Normal Weather Maps, Northern Hemisphere (U. S. Weather Bureau, 1946) for 40-year period; sea level data from U. S. Coast & Geodetic Survey.

There is evidence of active change of sea level in relation to land, especially at Galveston, during the past few decades (Marmer, 1948, 1949), where a total rise of 0.82 feet in 38 years has been observed. While this may be in part an indication of eustatic rise in sea level, the greater part of this change is probably due to local tilting. Similar changes have been observed on the Atlantic coast, also, but strictly comparable world data are difficult to obtain.

The tides of the Gulf of Mexico are of two types: the daily type with one high and one low for each 24-hour period, and the mixed, semi-daily type with two highs and two lows. These two types correspond with the declinations of the moon, and differ markedly in amplitude. The tropic tides have the larger amplitude. As a consequence of their smaller range, the equatorial tides are less effective in the exchange of water between the Gulf and the bays. A feature of the mixed tidal pattern is the vanishing tide, or loss of phase during the equatorial part of the tidal cycle. The vanishing tide of the Gulf of Mexico occurs above mean sea level, and results in a high stand of the sea for a day. Within the bays, the effect of this tide is exaggerated, so that the high stand of the tide may last several days, depending on local conditions.

The tidal pattern of the enclosed bays is essentially the same as that of the Gulf, but the ranges are reduced and the actions often damped, and altered by wind action. During hard northers water in the bays may be lowered by the combination of low tide and wind action. When temperatures are low enough to kill fish, the coincident

lowered water level may trap many fish which would otherwise escape before the cold could affect them, thus adding to the mortality.

III

The Environments and Their Characteristic Faunas

Despite the wide ranges of environmental conditions and the transitional character of many marginal areas, there are several discrete types of environment on the Gulf Coast. The environments as a whole may be divided in two general parts: estuarine, and neritic. By the latter is meant the environment of the shallow waters near the coast, from the open Gulf beach to the edge of the line of coral heads. Since this discussion is based, not on the natural limits of this environment, but upon information from trips with commercial trawlers and sporadic investigations on small research vessels, it cannot be said at this time whether the neritic environment of the northwestern Gulf of Mexico extends to the edge of the slope or ends somewhere before the change in gradient that marks this geomorphic division.

Burkenroad (1934) recognized three environmental areas in the waters of Louisiana west of the Delta: 1, estuarine, or "inside,"; 2, inner littoral, or "green water,"; and 3, outer littoral, or "blue water." This is also substantially true of Texas waters, except that the green water zone is often much narrower, and, insofar as character of water is concerned, undergoes pronounced seasonal changes, often becoming so narrow in summer that "blue water" is within sight of the jetties. Comparatively little is known at this time concerning differences in the pelagic fauna associated with these water types. There is, according to Burkenroad, a dearth of large algae in the inner littoral, the chief bottom cover being *Bougainvillia* (a hydroid) and a bushy bryozoan. On the Texas coast this difference does not seem to be pronounced; the large hydroid is uncommon and the bryozoan is sporadic in its occurrence. The primary differences are dependent principally upon the character of the bottom, *i.e.* whether muddy, sandy, or mixed.

Before the advent of contemporary culture, the coastal environment in the northwestern Gulf of Mexico was lacking in any areas of hard, stable substrate at tide level except the exposed parts of oyster reefs. The construction of jetties has provided a few small areas of artificially rocky coast, which break the naturally monotonous reaches of sand and mud. Practically speaking, the environment provided by the jetties extends barely below the intertidal (perhaps 30–40′ at the seaward ends), and are at most 7–8 feet above sea level. Elsewhere, the sandy beach continues as a physiographic climax from the Rio Grande to Cameron, Louisiana, where it is reduced to small reaches of coast between muddy and marshy shores.

1. The Offshore Bottoms

From a few hundred yards off shore to depths of 100–150 feet, and perhaps farther, the bottom of the Gulf of Mexico is occupied by an assemblage of sessile, sedentary and motile invertebrates and bottom-feeding fishes, whose most conspicuous members are various species of penaeid shrimp. Isolated patches and individual plants of algae, *Gracilaria* and *Digenia*, also occur on these bottoms, but no extensive beds are known. These shallow offshore grounds are of considerable extent because of the very gentle slope of the bottom. The ten fathom line is from 5–10 miles offshore along the

south Texas coast, and from Galveston to the Delta it is 35–40 miles from shore. The hundred fathom line is from 25–30 miles offshore along Texas, and as much as 140–150 miles offshore south of Louisiana. Along the outer edge of this shelf, in depths of 90–100 fathoms, occur the peculiar elevations (only recently mapped in any detail) rising to within 25–30 fathoms of the surface. Most of these are surmounted by small patches or reefs of coral and algae, and still smaller patches of coral are found nearer shore, particularly along south Texas. The bottom sediments of this shallow region consist of sandy mud near shore, and blue mud farther out (Thorp, 1931; U. S. H. O. charts 1126A-B). A description of surface turbidity conditions near the Delta is given by Seruton and Moore (1953).

These shallow bottoms are rich in nutrients, derived in part from the Mississippi and other rivers and swept westward by the shore currents which prevail along the northern coast of the Gulf of Mexico throughout most of the year.

Several invertebrates, in addition to the shrimp, are abundant here. The most common species, at least down to ten fathoms, is the sea pansy, *Renilla mülleri* (Gunter, 1950b). This alcyonarian is taken in almost every trawl haul from this region, sometimes by the hundreds. A commensal scale worm, *Lepidonotus sublevis*, is often found on the individual colonies. Also associated with the sea pansies is a nudibranch *Arminia tigrina*, which probably preys upon them, after the manner of its Californian congener (Johnson and Snook, 1927, pp. 498–499). More spotty in distribution than *Renilla*, but abundant in some localities, is the gorgonian *Leptogorgia setacea*. Like the sea pansy, it also supports a small association of organisms, including a gastropod, *Simnia uniplicata*, and the wing barnacle, *Balanus galeatus*. Other benthic invertebrates include an anemone, *Paranthus rapiformis*, and the sea stars *Luidia clathrata* and *alternata*. Worms of the family Onuphidae, including *Diopatra cuprea*, are evidently common, since the upper ends of their characteristic tubes, constructed of small clam shells laid down like roof tiles, are often brought up in trawls. The worms are seldom taken by this gear. Since our present knowledge of the bottom fauna is based principally on catches by trawls, it is limited to the larger, less active organisms. Few burrowing forms are taken; bivalves are scarce in the catches, although large gastropods, especially *Busycon contrarium*, which prey on such bivalves, are common. Very large gastropods are now rare on the heavily worked trawling grounds, since they are often kept by the fishermen as souvenirs or sold to curio dealers.

In addition to the shrimp, various other crustaceans occur on these grounds. The stomatopod *Squilla empusa* is locally abundant. Several crabs, including *Calappa springeri*, *Hepatus epheliticus*, *Persephone punctata*, *Portunus gibbesi*, *P. spinimanus* and *Callinectes danae* are widespread. Of these various crabs, *C. danae* is the most abundant. Several species of hermit crabs occur, the most spectacular of which is the large red hermit, *Petrochirus bahamensis*. The large shells occupied by this crab (*Busycon*, *Dolium*, and *Murex*) support a miniature community of bryozoans, the anemone *Calliactis tricolor* (often several individuals on a large shell), scale worms and the small commensal porcellanid crab *Porcelana sayana*.

Among the more motile invertebrates, the shrimp are of course the most abundant. The most common are *Penaeus setiferus*, the common commercial shrimp, *P. aztecus*, the brown or Mexican shrimp, *P. duorarum*, the pink shrimp, (absent, however, from Louisiana), and *Xiphopeneus krøyeri*, the sea bob. This by no means completes the roster of penaeids: *Trachypeneus similis* and *T. constrictus* are not rare, and there are

also two species of "hard shell" shrimp, *Sicyonia dorsalis* and *S. brevirostris*, as well as several less common representatives of the family in these waters. Among the motile invertebrates should also be mentioned at least two species of squid, *Lolliguncula brevis* and *Loligo pealei*.

Several species of fish living on or near the bottom are important members of the bottom community. These include the following: the sand trout, *Cynoscion nothus*, the croaker *Micropogon undulatus*, the threadfin, *Polydactylus octonemus*, the catfish, *Galeichthys felis*, and others (Gunter, 1945a, p. 94).

Other than Gunter's work on the seasonal distribution of the fishes and larger invertebrates (1945a, 1950b), there has been no attempt at a quantitative analysis of the fauna of the shrimping grounds. There is preliminary evidence that there are several communities, each characterized by a somewhat different assemblage of organisms, but their areal limits are yet to be determined.

The most spectacular evidence is that of the shrimp fishery itself. Up to 1948 the great bulk of the shrimp catch consisted of *P. setiferus*, obtained from near shore to about the 10 fathom line. In the last few years a decline in the abundance or availability of *P. setiferus* has stimulated a fishery for *P. aztecus* in deeper water and *P. duorarum* off Campeche and north of Key West. It was discovered that these species, the "brownies" and "pinks" of the fishermen, could be captured at night in depths of about 10 to 30 or 35 fathoms, the pinks on shell-sand bottoms. There is preliminary evidence that the association of bottom invertebrates is different; the sea pansy is less abundant in waters beyond 15 fathoms, where it is replaced by a small sea star, *Astropecten antillensis;* and two bivalves, *Pitar cordata* and *Chione latilirata*, are commonly brought up in the trawls, according to Mr. Henry Hildebrand.

There are some apparent differences in the fauna north and south of about 27° N. Trawl catches off Port Isabel often contain numbers of the ascidian *Styela plicata*, which are rare in Port Aransas hauls. The large red hermit crab, *Petrochirus bahamensis*, is more abundant in the south, as is *Murex fulvescens*. Echinoderms, because of their notoriously spotty occurrence, are unreliable indicators for local faunal changes in this region, but one conspicuous ophiuran, *Ophiolepis elegans*, was common in the Gulf near Port Isabel in 1947 but has not been collected off Port Aransas. This also seems to be true for the echinoid *Clypeaster ravenelli*, and the large holothurian, *Stichopus badinotus*. It may be that these echinoderms are excluded from the northern area because of salinity and sedimentation conditions, or perhaps they are simply not found at the usual trawling depths in these areas.

Nevertheless, the faunal assemblage is basically the same from Port Isabel to the Delta, wherever salinity conditions permit. In the northeast Gulf there seems to be a somewhat higher percentage of tropical forms, especially spider crabs. The crown shell, *Melongena corona*, is common near Pensacola but of unproven occurrence in Texas waters. The most conspicuous difference is the occurrence of various sponges, especially commercial varieties, in the northeast Gulf. Sponges of any variety are rare in Texas and Louisiana waters except the widespread boring sponges *(Cliona)*. These differences seem to be associated with the counterclockwise eddy which carries tropical water northward along the western coast of Florida.

Seasonal variations in the invertebrate populations are incompletely known. According to Gunter's data, *Renilla mülleri* is more common in the spring. There are

two population peaks for *Penaeus setiferus*, a spring peak of adults, and a fall peak of juveniles. Soon after hatching, these shrimp move into the bays to feed, and return to the Gulf in the fall as the waters begin to cool. There are also indications that *Penaeus setiferus* may spawn twice within the first year of its life, so that there may be two spawnings in a year and a half. The brown shrimp, *Penaeus aztecus*, has a somewhat different life cycle. The adults apparently spawn in deeper water (beyond 10 fathoms) than *P. setiferus* and do not return to the coastal waters (Burkenroad, 1939). The shrimp are dependent then, not only upon the food resources of the bottom communities of the shallow Gulf, but upon those of the bays as well. In recent years the combined shrimp catch of Texas and Louisiana has been around 115,000,000 pounds annually. When it is remembered that the largest *P. setiferus* weigh about 10 to the pound, and *P. aztecus* perhaps 4 to the pound, but that the average sizes in the hauls are much smaller, some idea of the magnitude of these populations may be obtained.

Variations in the movements of water masses and supply of available nutrients are reflected in fluctuations of populations. Often in the spring months there are conspicuous local diatom blooms forming yellowish films on the surface. Conditions bringing about catastrophic mass mortality of fishes and invertebrates of the sort which occur sporadically along the west coast of Florida (Gunter *et al.*, 1948) are rare in the northwestern Gulf. One such occurrence was observed in 1935 (Lund, 1936). The Florida mortalities of 1946–47 were associated with a bloom of the dinoflagellate, *Gymnodinium brevis*. This episode was the most spectacular one in a region where such occurrences have happened again and again; less serious "red-tide" outbreaks occurred in August-September, 1951, and in 1952–53. The 1951 bloom was said by (Howell, 1953), due, to *Gonyaulax monilata* while Chew (1953) attributes the 1952 episode to *Gymnodinium*. Dinoflagellaete blooms are relatively common in the ocean, especially in regions of upwelling, and are often associated with mass mortalities, as on the coast of Southern California. A general account of red water occurrences has been compiled by Hays and Austin (1951); see also Brongersma-Sanders (1948).

Adequate studies of the bottom communities of Gulf waters and of the fluctuations in their populations are not yet begun, since such studies depend on a thorough understanding of the oceanography of these waters. The intensive researches recently begun in the northern Gulf of Mexico by several agencies and institutions may in time provide the basis for a rational analysis of the bottom communities, although at the present time no adequate data on the fluctuations of the shrimp populations are being gathered. In the meanwhile, we must agree with Burkenroad (1946) that "the dynamics of American marine ecosystems are little understood."

2. The Bays

A. Biotic Divisions

The two natural physiographic divisions of the bays, the shallows, and the deeper basins, are occupied by correspondingly different biotic communities (Fig. 28). A third natural division is that formed by the oyster reefs (Gunter, 1945a, p. 93). The steeper slope which separates the flats from the basin proper might be regarded as being analogous to the continental slope of an ocean basin although the magni-

FIGURE 28

Aerial view of southern part of Aransas Bay, with Rockport to the right. Note the shallow, grassy flats in the foreground and the sand bars in left center. (Photograph by Francis P. Shepard, 1951.)

tude is only a hundredth of that of the continental slope. The shallow inshore region is often occupied by extensive beds of turtle grass *(Thalassia testudinum)*, various bushy algae, especially *Gracilaria confervoides*, and stands of emergent salt grass *(Spartina)*. The turtle grass beds may be mentioned as important feeding grounds for migratory waterfowl which winter along the coast.

The bottom material varies from sand to fairly firm mud, or soft mud covered with plant detritus. Often there are oyster shells which afford shelter for small crabs and pistol shrimp. The characteristic inhabitants of this bay shelf region are the various cyprinodont fishes and the grass shrimp (*Palaemonetes* spp.) (Gunter, 1945a, p. 93), comprising a *Cyprinodontes-Palaemonetes* community. This same association of a cyprinodont and a palaemonid occurs in the estuaries and grassy flats along the Tunisian coast (Seurat, 1929). The primary requisite for these animals seems to be shelter (Gunter, *ibid.*, p. 94); they are seldom found away from the shallows or some sort of plant growth, although the variations in temperature and salinity in such shallows are greater than anywhere else in the bays or the Gulf. The extent of these flats varies with season, as only a few inches change in bay level may increase or decrease the area under water several fold. A similar relationship between rooted vegetation and fishes has been recognized in fresh water (Dansereau, 1945).

A specialized extension of the shallow water area is found in the ponds of the marshes and salt flats bordering the bays. Conditions are more extreme, and aquatic plant cover is greatly reduced, but since predatory fish are also absent, the environment still offers shelter to the small fishes and shrimp. The variety of the fauna is reduced, but the populations are abundant and the ponds are important feeding grounds for many aquatic birds. The life of some of these ponds is described by Gunter (1950c) and Hedgpeth (1950).[6]

The shallows and ponds are also the habitat of various burrowing polychaetes and burrowing anomurans *(Upogebia* and *Callianassa)* a hermit crab *(Clibanarius vittatus)* and several small gastropods, especially *Neritina virginea*. A small mud crab, *Rhithropanopeus harrisii*, is common in the shallows of the less saline bays. Clams do not form extensive beds, in fact, are rare in this environment, perhaps because of the fluctuating water level. Among the transient or seasonal members of these ponds and flats, juvenile blue crabs and penaeid shrimp are the most important. These areas are in fact the most important nursery grounds for the younger stages of these crustaceans. The marshy borders of the ponds and shallows are occupied by large colonies of various species of fiddler crabs *(Uca)* and marsh crabs *(Sesarma)*, the salt marsh periwinkle *(Littorina irrorata)*, and the pulmonate *Melampus coffeus*.

The deeper, or offshore waters, of the bays are the haunts of larger crabs and shrimp, croakers, catfish, and many other fishes of more or less seasonal occurrence. The fish fauna of the various bay areas has been described in some detail by Gunter (1945a). The benthic invertebrates of the deeper parts of the bays are still inadequately known. Beds of various bivalves occur in somewhat spotty fashion,

[6] A more detailed account of this particular area (on the Aransas National Wildlife Refuge), with special reference to the whooping crane, is given by Allen (1952). The illustration on page 131 should be labelled *Callianassa jamaicense* instead of *Crangon heterochaelis*. I owe Mr. Allen an apology for my absent-minded omission of a pair of legs from the figure of the *crawfish* on p. 117!

and apparently fluctuate from year to year. The lower parts of the bays, near the passes, are invaded in summer and during dry years by such animals as various echinoderms, including *Arbacia punctulata* and small brittle stars, the coral *Astrangia astraeiformis,* and larger gastropods, especially *Fasciolaria distans, Polinices duplicata,* and an occasional *Murex.* In Lydia Ann Channel (lower Aransas Bay) there are colonies of *Trachycardium muricatum, Ostrea equestris,* and *Arbacia punctulata,* with numbers of small crabs, especially *Hexapanopeus angustifrons* and *Heterocrypta granulata.*

B. The Oyster Biocoenosis

The most characteristic and important biotic aggregation in the bays, both from the viewpoint of its effects of the physical environment as well as from that of human economics, is the oyster reef. The conditions under which the American oyster, *Crassostrea virginica,* builds reefs are a mean temperature range between 10–25° C, regular influxes of fresh water bringing about a mean salinity range between 10 and 30 o/oo, relatively shallow depths, but apparently not tidal exposure, and a bottom of mud or sandy mud. Conditions within these ranges evidently exist from the Gulf of St. Lawrence to well down the eastern coast of Mexico, but are at optimum for the oyster in such regions as Chesapeake Bay and some parts of lower Louisiana. Where salinities and temperatures exceed the optimum, the oyster occurs in scattered clusters in the intertidal region rather than in subtidal reefs.

The typical oyster reef on the Gulf coast is, in cross section, a low mound with a high center or "hogback," which is occupied by dead shells, with the live oysters on the sloping shoulders. These reefs occur on muddy bottoms, widely distributed in bays of lower salinities, but more or less restricted to the upper ends of those bays which are subject to the invasion of higher salinities through the passes from the Gulf during the periods of low rainfall and decreased run-off. A natural reef is usually oval or spindle-shaped, or is in the form of a narrow bar extending from the shore. Although reefs in Texas have been badly cut up in recent years by artificial channels and mudshell dredging, so that the pattern is now obscured, the usual location of such reefs is such that their long axes lie at right angles to the prevailing currents of the bays (Gunter, 1945a, p. 11). This is especially well illustrated in the Copano-Aransas Bay area (Figure 29), and in some of the older survey papers which record conditions before extensive man-made changes altered the natural patterns of the reefs (Figure 30). In Moore (1907), for example, the chart shows the north arm of Matagorda Bay with a series of reefs that lie directly across the bay below the mouth of the Colorado River. Since that time, the Colorado River has built a delta across Matagorda Bay and now drains directly into the Gulf. This change, probably inevitable geologically, was accelerated by the dynamiting of a long-standing log jam about 1932 (Price and Gunter, 1942). As a result, many of the reefs charted by Moore no longer exist as oyster reefs, being covered with silt, and Halfmoon Reef has also died off, possibly because of the changes in current patterns at the confluence of Trespalacios and Matagorda bays induced by the altered course of the Colorado. The patterns of reefs in relation to the currents are not always so diagrammatically arranged as in Copano or pre-engineering Matagorda Bay. In Lavaca Bay, the larger part of the reefs are evidently so oriented, but a considerable area of reefs occurs along the shores, evidently in response to eddy patterns (Figure 31).

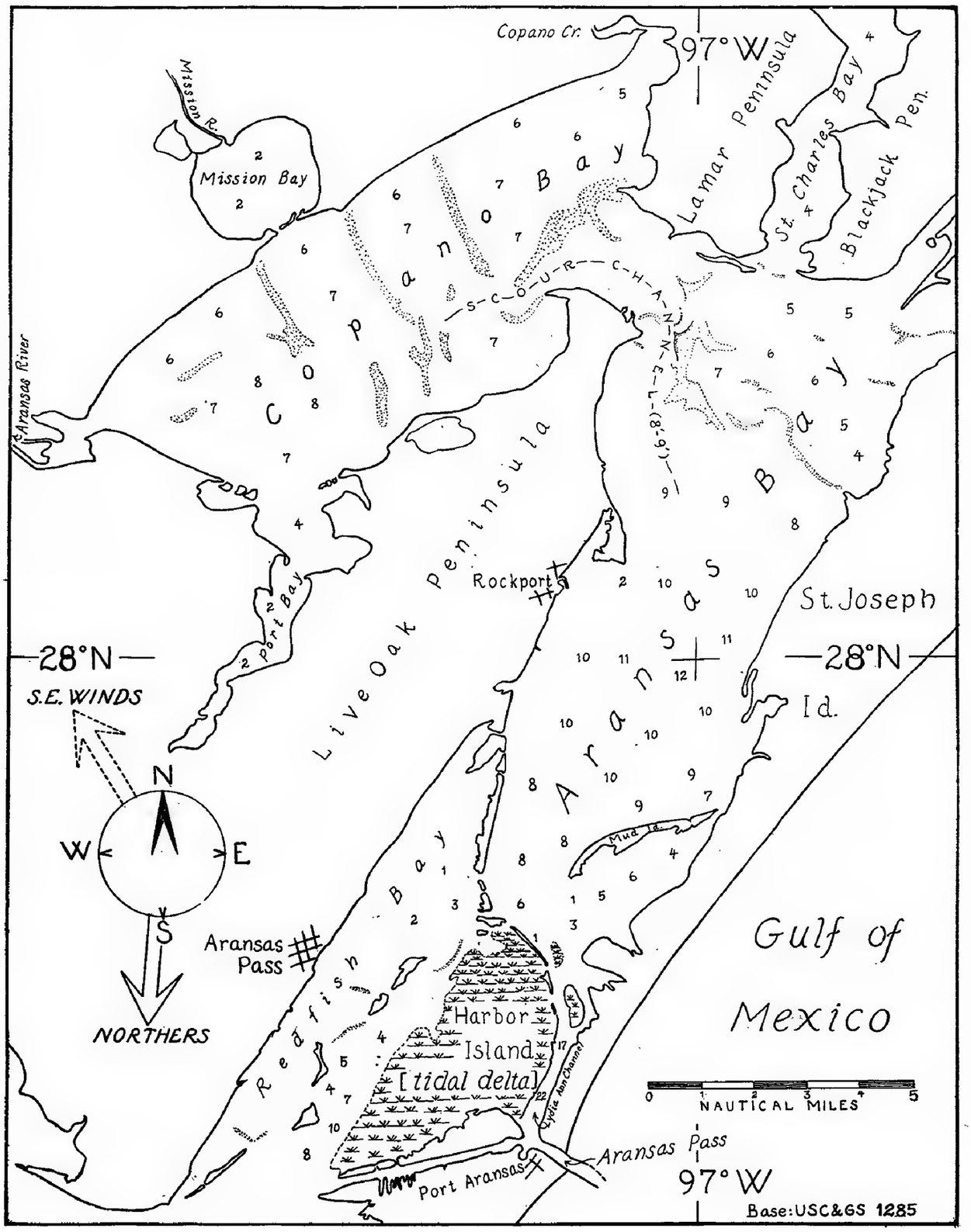

FIGURE 29

Map of Copano and Aransas bays, showing the larger oyster reefs (stippling), prevailing winds, and other features.

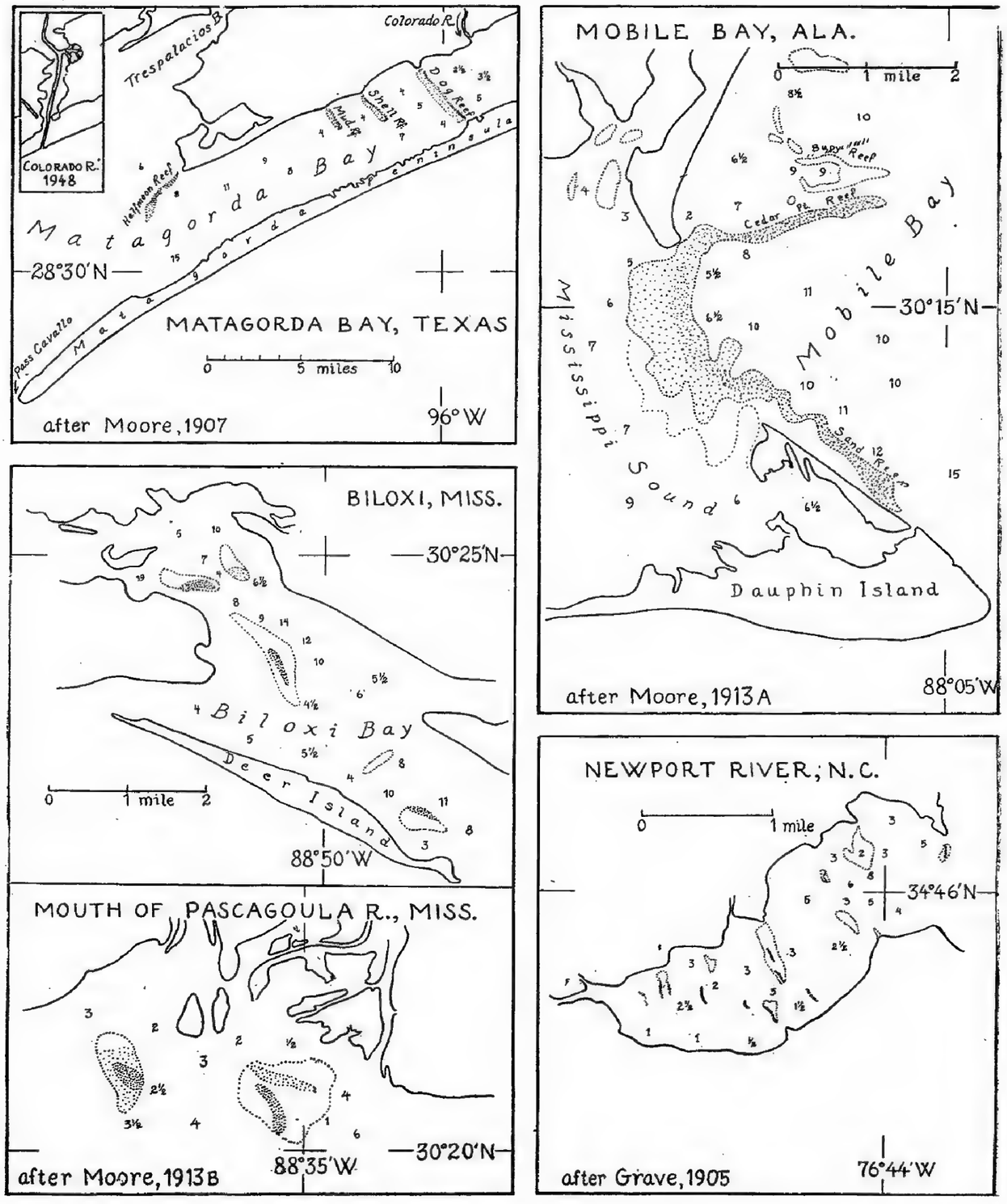

FIGURE 30

Oyster reefs in various Gulf coast localities, together with an example from North Carolina. From the indicated sources.

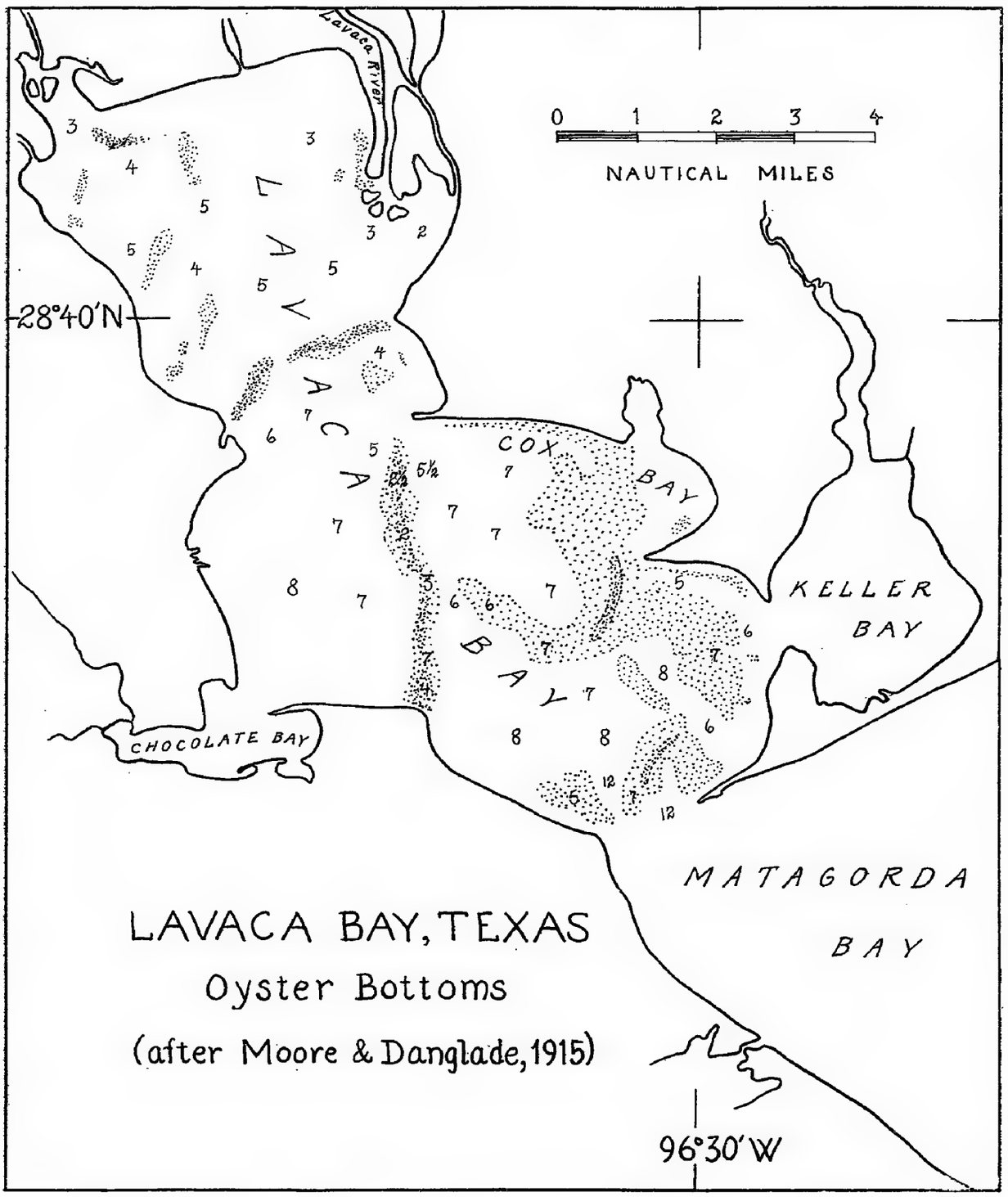

FIGURE 31

Oyster reefs in Lavaca Bay, Texas, showing larger reefs lying across the main axis of the Bay. Modified from Moore and Danglade, 1915.

The manner in which oyster reefs develop, eventually forming bars transverse to the prevailing currents of a bay, was examined by Grave (1905). The stages in the formation of such a transverse reef are illustrated in Figure 32. Grave suggested that

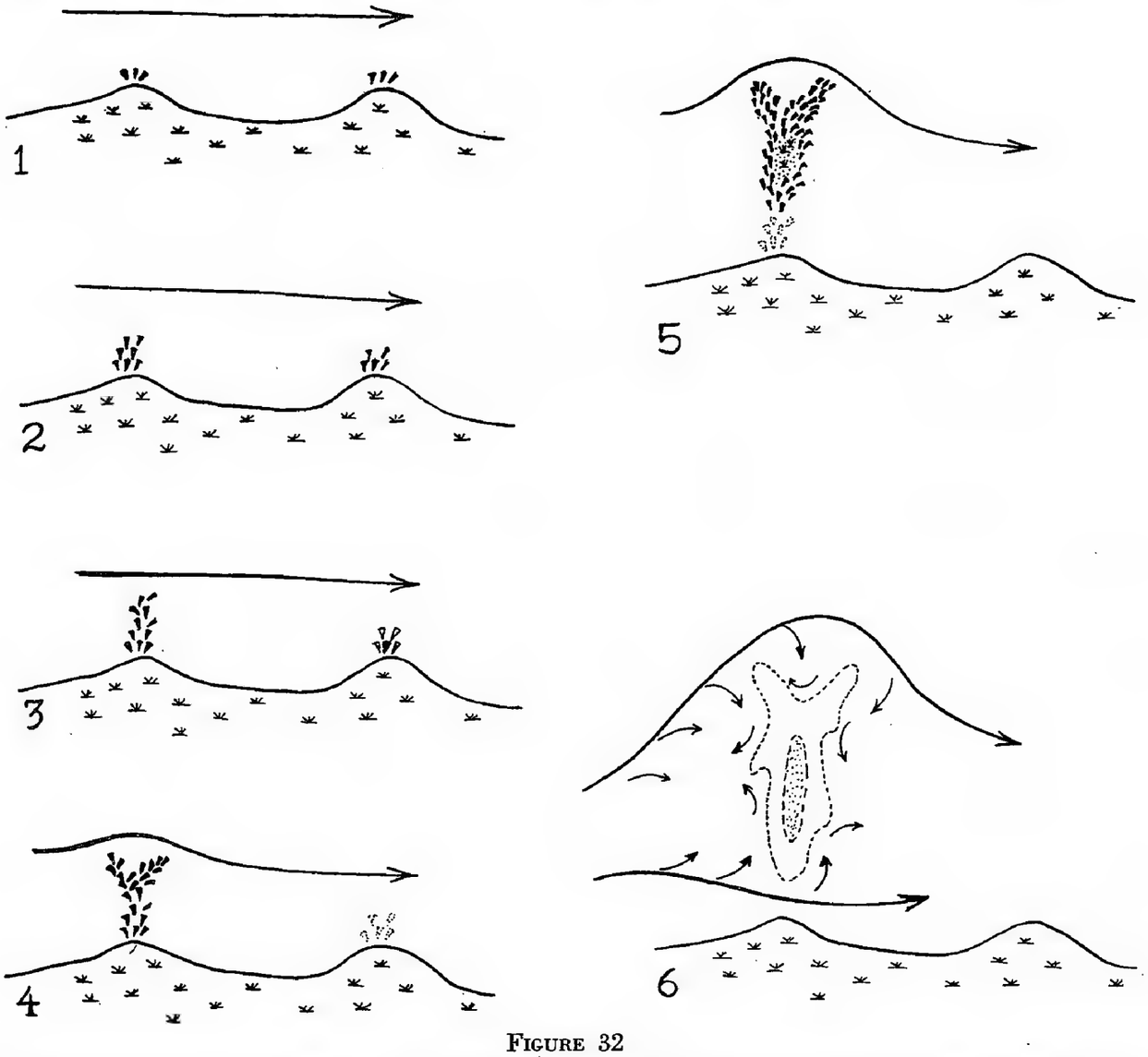

FIGURE 32

The origin of transverse oyster reefs, according to Grave's hypothesis. Modified from Grave, 1905.

the oysters located nearest the current thrived best, so that oysters settling on small promontories along the shore grew faster than those elsewhere. Later generations would then attach to the shells of oysters already in place, and those nearest the current and the best food supply would grow at the expense of the others. This process would also starve out a reef beginning immediately downstream. As the reef continues to grow, it will eventually become large enough to divert the current, causing small counter eddies which in turn promote branching at the tip of the reef. The next stage in the growth of a reef is the separation from the shore by the death of the original starters of the reef. Finally, the center is built up out of water to form a shell island.[7]

[7] Unpublished studies show that oyster reefs fall into at least two categories: those that extend outward from a shore or near-shore area according to Grave's hypothesis, and those that are elongated parallel with some demonstrable current in which they lie, as reefs parallel with the main tidal current of lower James River, Virginia, and parallel with the long axis of San Antonio Bay, Texas. The numerous oyster reefs in the quiet brackish waters of the Gulf of Mexico along the northern part of peninsular Florida seem also to fall in the two categories noted, but have not been studied in detail [W. Armstrong Price].

Oysters are not only formers of reefs, they are dominant members of a natural community of organisms. The recognition of this natural entity, a "biocoenosis" by Möbius marked the beginning of modern ecology as a science devoted to the study of biotic aggregations (Möbius, 1883, 1898). According to the classification advanced by Clements and Shelford (1939, pp. 336–338), the oyster community is to be considered a "fragmented faciation" of the "*Macoma-Mya* biome." Since *Mya* has not been reported from the Gulf Coast and beds of *Macoma* are small and inconspicuous, this classification does not have much meaning for the Gulf Coast. Furthermore, it seems to imply that the oyster community is a secondary phenomenon surrounded by a clam bed, which is certainly not the case for the American oyster under optimum conditions. We have, in *Crassostrea virginica*, an organism which is capable of providing, in the form of reefs, its own substrates, and which provides, especially on the Gulf Coast, where there are no rocks, the only available natural hard substrate for many of the sessile invertebrates occurring in the bays. If not a "major benthic division," the oyster reef is certainly an important subdivision of the bay environment. Where it builds actual islands it is a terminal, or climax, formation. The actual structure, whether it is to be called a reef or a biostrome, is therefore the end product of a natural process which can be reversed only by physiographic changes. The mudshell deposits of the bays, which are actually buried reefs, are evidence that such physiographic changes are part of the long term fluctuation in the environment of the Gulf Coast. At the present time there are small colonies of oysters near Port Isabel, in the southern end of the Laguna Madre, a demonstration of the other extreme (Figure 33). Evidently these oysters, which occur in clumps or "towheads" rather than in reefs, are survivals of the not-too-distant past when overflow from the Rio Grande freshened this part of the Laguna. How long these oysters will endure under the present conditions is unpredictable. Successful spawning is rare. According to Amemiya (1928), salinities higher than the optimum interfere with development of the Japanese oyster by inducing separation of the blastomeres and the production of abnormal embryos.

The fauna associated with the oyster beds in the lower Laguna is markedly different from that found in the meso- and polyhaline waters of the bays from Aransas Bay northward (Figure 34). The most conspicuous animals are an agile brittle star, *Ophiothrix angulata*, and a brown anemone, *Aiptasia pallida*. Occasional specimens of the brittle star have been found at Port Aransas under rocks, but not on oysters in Aransas Bay, and the anemone is unknown from this association in that bay. A few small specimens of the sea cucumber *Thyonacta sabanallensis* occur on oyster clumps at Port Isabel, but farther north this species is not found in the bays. A few small specimens of the mussel *Brachidontes exustus* are found on the oyster clumps in South Bay, but these appear to be, on the average, smaller than those farther north. The terebellid, *Thelepus setosus*, is common at Port Isabel and on the oysters, but the porcellanid crab *Petrolisthes armatus* is much less numerous than in the Aransas Bay area to the north.[8] The fauna of these oyster clumps is on the whole marine rather than estuarine.

There appear to be large colonies of clams in the flats around Port Isabel; the beach drift along the southern shore of the Laguna Madre, just north of Port Isabel,

[8] The field data for this account were obtained in March–April, 1947; it should be remembered that the statements are made in reference to the fauna of Aransas Bay as constituted at that time.

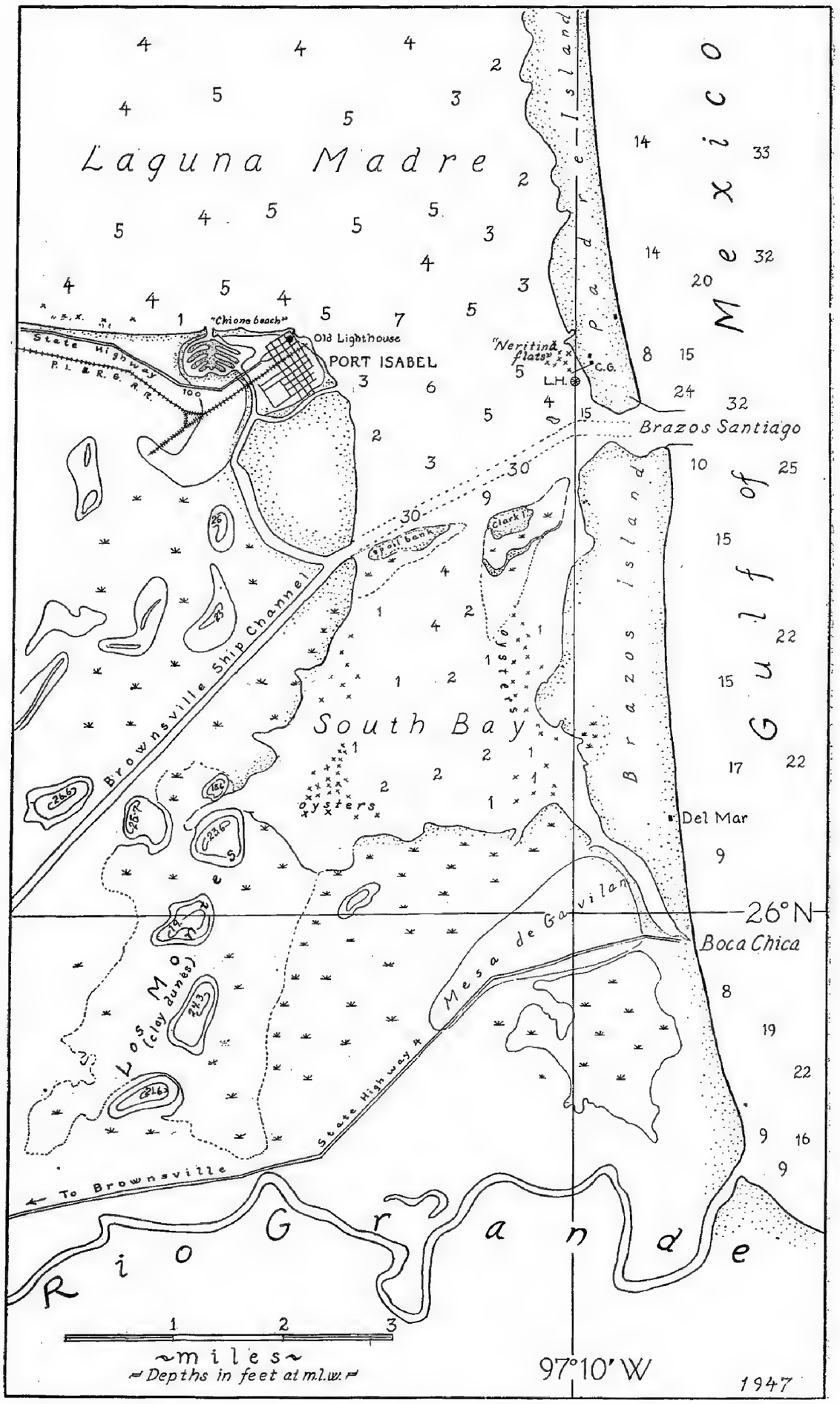

FIGURE 33

Map of the vicinity of Port Isabel, showing oyster grounds in South Bay.

consists in such a large degree of shells of *Chione cancellata* that was named "Chione beach" in field notes. Across the bay, north of the Coast Guard station, there is a shallow flat with scattered oyster clumps and a large population of *Neritina virginea*. There were so many of these shells on this flat, both living and occupied by hermit crabs, that it was named "Neritina flat" for field purposes. Also conspicuous in the beach drift along "Chione beach" are the shells of the opisthobranchs, *Haminoea elegans* and *Bulla occidentalis*.

FIGURE 34

Sketch of an oyster clump from South Bay, near Port Isabel. Animals represented include the anemone, *Aiptasia pallida;* the brittlestar, *Ophiothrix angulata;* the cucumber, *Thyonacta sabanallensis;* a chiton, *Ischnochiton papillosus; Brachidontes exustus, Crepidula fornicata,* and *Anachis avara*, various worms, barnacles, and a small xanthid crab.

In a recent resurvey of the oyster bank near Helgoland, one of the "type localities" of Möbius' biocoenosis, Caspers (1950b), found that the oyster-bank of 1875–1886 had disappeared completely. He could find only ten living specimens of *Ostrea edulis*, but did find an abundant population of *Nucula nucleus*. He attributes this change to ecological processes inherent in the nature of the oyster biocoenosis, the trapping of sediment by the shells, competition for food and reduction by enemies, bringing about a "succession" which may in turn prepare the way for a new oyster bed. The oyster bank in this region he considers to be a "Variationsgebiet" (faciation) of the *Nucula nucleus* community, and the present status of this community is a result of reciprocal interaction between biotope and fauna which is in a state of self-regulated "labile equilibrium."

Aside from the problem presented by this somewhat different use of the term "succession," it is difficult to compare this situation with an American oyster reef. The species involved are so different that they merit classification in different genera (Gunter, 1950a), and what is true of one oyster is obviously not true of another. There would seem to be as good a case for overfishing on the Helgoland bank as for this sort of circular sere with recurring climax which is implied in Casper's hypothesis. Things obviously are not the same as they were in Möbius' day, especially on the Helgoland oyster bank. Further information on *O. edulis*, especially of quantitative nature, is to be found in the papers of Hagmeier and Kändler (1927) and Mistakidis (1951).

Certain organisms can be considered intimate members of the oyster biocoenosis. These are the organisms found almost exclusively associated with oysters, or which are actively predaceous or parasitic upon them. It is this latter group, of course, that is of most interest to those concerned with the practical aspects of oyster biology, either as commercial growers or fisheries biologists. It is also this group of organisms which has received most notice in general works on the oyster (Orton, 1937; Ranson, 1943), and in the various surveys of oyster bottoms which have been published by federal and state investigators in this country. It is usual to consider these organisms as "enemies and pests."

The most important organisms in this category, as far as the Gulf Coast is concerned, are the fungus *Dermocystidium*, such internal parasites as the gregarine *Nematopsis*, whose alternate hosts include various mud crabs of the family Xanthidae, and the trematode *Bucephalus* which is carried by some unidentified species of fish, and such active predators as the polyclad *Stylochus*, the large active crabs *Callinectes sapidus* and *Menippe mercenaria*, and the predaceous gastropod, *Thais haemastoma*. Possibly the ubiquitous small gastropod *Odostomia impressa*, abundant on oysters in Louisiana and less common in Texas, is also a predator, as suggested for these pyramidellids elsewhere (Fretter and Graham, 1950). Another group of organisms infests the shell of the oyster, weakening it or causing the oyster to devote its energies to repairing the damage by building layers of shell over the irritating invaders. These include the boring sponges, *Cliona*, the boring clam, *Martesia*, and the polychaete worm, *Polydora*. Still other organisms, such as sponges, mussels, barnacles, bryozoans, serpulid worms, anemones and tunicates, by settling on the surface of the oyster shell, offer competition for food and living space.

In an analysis of the *Ostrea edulis* biocoenosis of the Oosterschelde, Korringa (1951) considered the shelter provided by the shells to be one of the most im-

portant ecological factors enabling the development of a rich epifauna. Other factors considered include the possible source of food from the by-products of the oysters and possible freedom from sedimentation induced by the activity of the oysters. These two possibilities are hard to reconcile with Korringa's finding that there was not much difference between the epifauna of dead shells and of living oysters.

Some of the organisms comprising the epifauna of oysters, especially the tunicates, and bushy bryozoans *(Bugula)* are seasonal in occurrence on the Gulf Coast, developing into lush colonies during the cool months of the year and nearly disappearing in summer. Others, like *Thais* and the boring sponges, are usually serious pests during the summer dry periods, when salinities are higher, and do not thrive in periods of low salinity. Mussels *(Brachidontes recurvus)* thrive in the lower parts of the salinity gradient, and die off when the oysters are transplanted to waters of somewhat higher salinity. This decrease of mussels in higher salinity may, however, be related to an increase of *Thais,* which either prefers mussels or finds them an easier prey species, as suggested by Burkenroad (1931) for Louisiana waters. A similar relationship between bivalves and their gastropod predators has been observed in New Jersey waters by Carriker (1951), who found that mussels seem to be preferred over oysters and *Venus.* De Laubenfels (1947) suggested that boring sponges might be reduced by moving the oysters to less saline waters, or immersing them in fresh water, for a short period.

It will be noted that several organisms which are important pests in other parts of the world are missing from Gulf waters. Texas and Louisiana bays are blest, as far as the oyster is concerned, with a lack of predaceous starfish; although there are several in the shallow waters of the Gulf, they belong to the genera *Astropecten* and *Luidia,* and are not capable of attacking oysters. The oyster drill, *Urosalpinx,* is also absent, although there is a very similar snail, *Cantharus cancellaria,* which probably has been mistaken at times for *Urosalpinx.* It occurs chiefly on the jetties, where it may attack oysters, but *Thais* is a much larger and greedier predator. Although *Crepidula fornicata* is not rare, especially on the Texas coast, it is never abundant enough to be a competitor for food, as it is claimed to be on the coasts of England and Holland, where it was accidentally introduced from North America.

3. The Passes

The passes or inlets constitute the vital link between the bays and the Gulf of Mexico. It is through these passes that drainage waters must be discharged, and through them that the tides bring new supplies of sea water. They are also the highways by which fish, shrimp and crabs migrate from the bays to the Gulf to spawn, and their young enter the bays to feed. Because of the more irregular shore line of Louisiana, passes are less important in controlling the movements of these populations. On the Texas coast, however, there are only a few large passes, and only one of these major passes, Pass Cavallo, remains in an approximately natural condition (Figure 35). The others are jettied, and with the exception of Brazos Santiago, are subjected to industrial wastes from nearby cities or installations. The jetties themselves form barriers to longshore migration, and may have some effect on the populations of those fishes and crustaceans which spawn in the surf zone of the outer beach. The jetties, walls of rock extending out into the Gulf a mile or

more, must certainly divert numbers of feebly swimming zoea and megalops of the blue crab into the Gulf. No serious study has yet been made of the effects of jetties and the concentration of pollution in the passes on the fauna of the bays, but it is certain that their effects are not insignificant. A general account of the fauna of the jetties is given by Whitten, Rosene and Hedgpeth (1950).

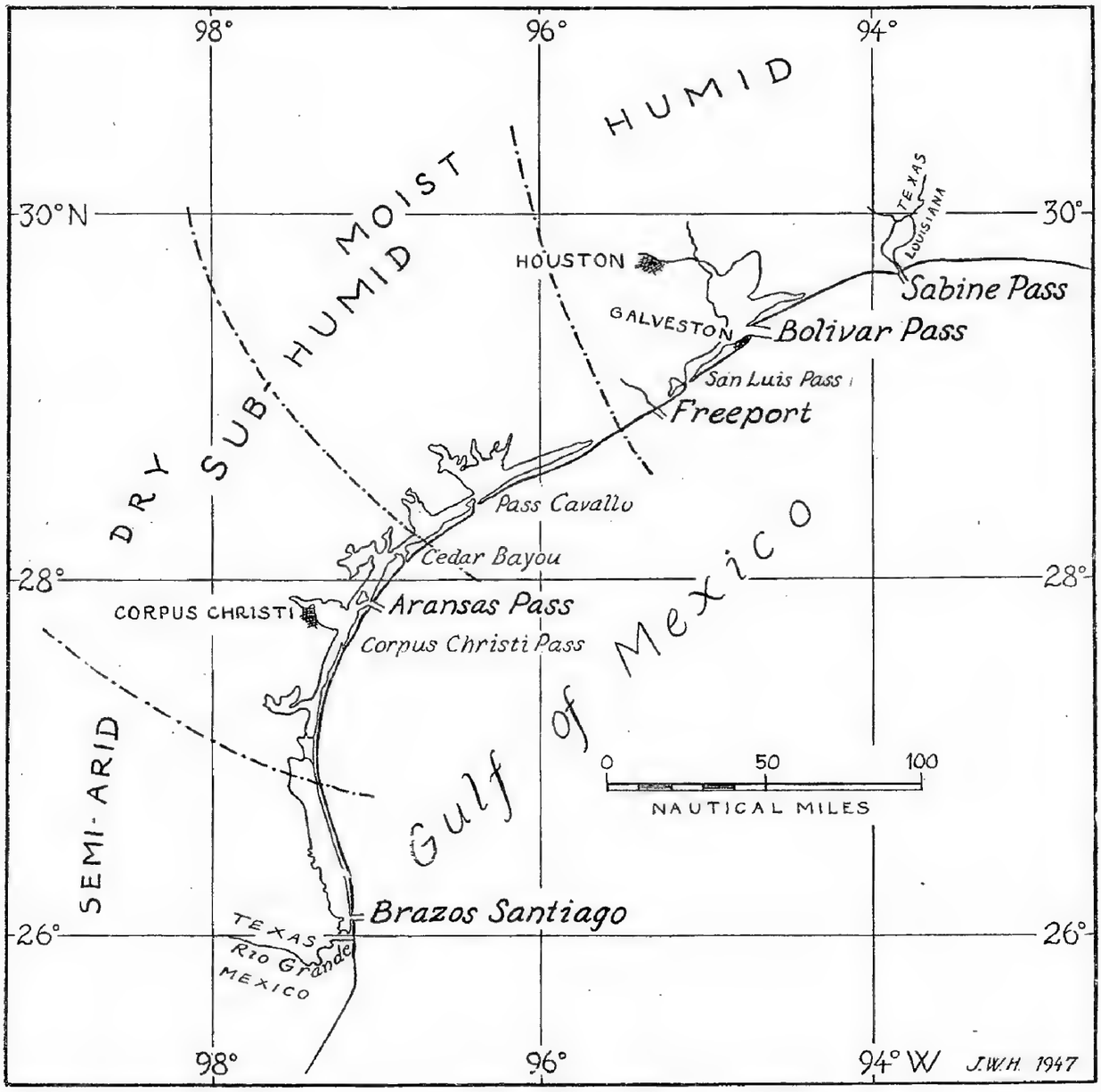

FIGURE 35

Location of passes and jetties on the Texas coast. (From Whitten, Rosene, and Hedgpeth, 1950.)

The fauna of the intertidal region just inside Aransas Pass, for example, does not seem to be as abundant as it might be. Whether this is a result of oil seepage from the tanker docks in the vicinity or because of the salinity variations in the pass remains to be determined. On December 27–28, 1947, counts of the conspicuous organisms under six rocks of approximately one square foot each in bottom area were made at Port Aransas and Rockport. The differences at this time were astonishing; particularly when it is remembered that salinities at this time were on the average lower at Rockport than at Port Aransas:

	Rockport	Port Aransas
Bunodosoma cavernata	78	8
Petrolisthes armatus	312	45
Anachis avara	102	10
Menippe mercenaria (juv)	15	3

There are at the present time no colonies of oysters and stone crabs near the inner region of the pass at Port Aransas. Such a *Crassostrea-Menippe* association occurred, at least up to the recent drought period, just inside Cedar Bayou. The large oysters occurred in scattered clusters over an area of several hundred square feet, partly exposed at low tide, with many young oysters ¼–½ inch in diameter on old shells and the larger living oysters. Stone crab burrows or forms were observed under almost every oyster cluster, or about one burrow per square yard. In almost every burrow there was a small blenny (*Hypsoblennius* sp.). A few large *Thais* were observed. Eleven stone crabs were collected and measured, ranging from 7 to 11 centimeters in carapace width. In slightly more than two sacks of oysters collected, some 15 or 16 *Pinnothers ostreum* were found. Only a single male crab was found in this lot. This *Crassostrea-Menippe* association extended to within about three feet of the shore line, where it ended abruptly, separated by a narrow band of muddy shore from the dry shell and grass of the island. Numerous specimens of *Littorina irrorata* were observed on the grass stems in this locality. (Observations made on November 23, 1945).

Since both oysters and stone crabs are sought after for food by man (the original vertebrate predator of the stone crab is the raccoon), it is possible that the absence of this association from the immediate vicinity of Port Aransas is a result of persistent foraging. The association occurs, however, in various parts of Harbor Island, although not as extensively developed as at Cedar Bayou in 1945. The Port Aransas vicinity is also peculiar in lacking any populations of the salt marsh periwinkle; during the years 1947–49 the author could not find a single living specimen of *Littorina irrorata* along the southern side of the channel, although this periwinkle is common on St. Joseph Island just across the pass.

4. Hypersaline Lagoons

Hypersaline lagoons, or metahaline waters occur in several parts of the world, including the south Texas coast. There are also several types of inland salt lakes, evaporation ponds, sinks, brine pools, playas, and the like, which are noted for their high salt content. The characteristics of each of these are so different that no general scheme of classification can be drawn up, although they have somewhat similar faunal characteristics. A summary of the faunal peculiarities of such inland salt waters will be found in Hesse, Allee and Schmidt (1951, pp. 440–445). The fauna of hypersaline lagoons, that is, marine lagoons connected more or less directly with the sea, is less well known. The most extensive studies of such regions have been the researchers of Russian fisheries biologists, especially in the Sivash or Putrid Sea, an arm of the Sea of Azov cut off from its parent body by a bar similar to Padre Island (see Zenkevich, 1947b, pp. 393–399 for a summary), and the work of the Cambridge Expedition to the Suez Canal in 1924 (Fox, 1927, 1928).[9]

[9] For a recent discussion of the biogeographical relationships of the Suez Canal, see Kosswig (1951), and Tortonese (1952).

Studies on other areas are fragmentary, and the entire problem of these hypersaline lagoons is yet to be synthesized. The nearest approach to such a synthesis will be found in Beadle's paper on Algerian salt lakes (1943a) and his general discussion of osmotic regulation and the fauna of inland waters (1943b). In the latter paper, Beadle offers a tentative classification of the types of saline-water animals. He recognizes three general categories, 1, normally fresh water animals commonly found in saline waters up to about 20 o/oo; 2, those preferring salt water, but limited to a salinity range not exceeding about 50 o/oo, and 3, those found in the highest salinities. Animals in the last category have the highest range of tolerance. "As a general rule the higher the salinity of the water the smaller the number of species capable of living in it, and consequently the less are the successful ones hampered by competition." (Beadle, 1934b).

Up to the opening of the Intracoastal Waterway in 1949, the northern and southern parts of the Laguna Madre were effectively separated by sand flats, which resulted in separate hydrographic economies except during periods of very high tides. Salinities, and possibly temperatures, were uniformly lower in the southern half. For various reasons, chiefly concerned with the operation of a light seaplane, it was not possible to obtain a representative series of temperature and salinity data for all months for the southern Laguna Madre, but for those months for which the data are comparable, the averages for the southern Laguna are somewhat lower, although the minima, at least, are lower in the northern half (Figure 36, Table 4). The reasons for this difference

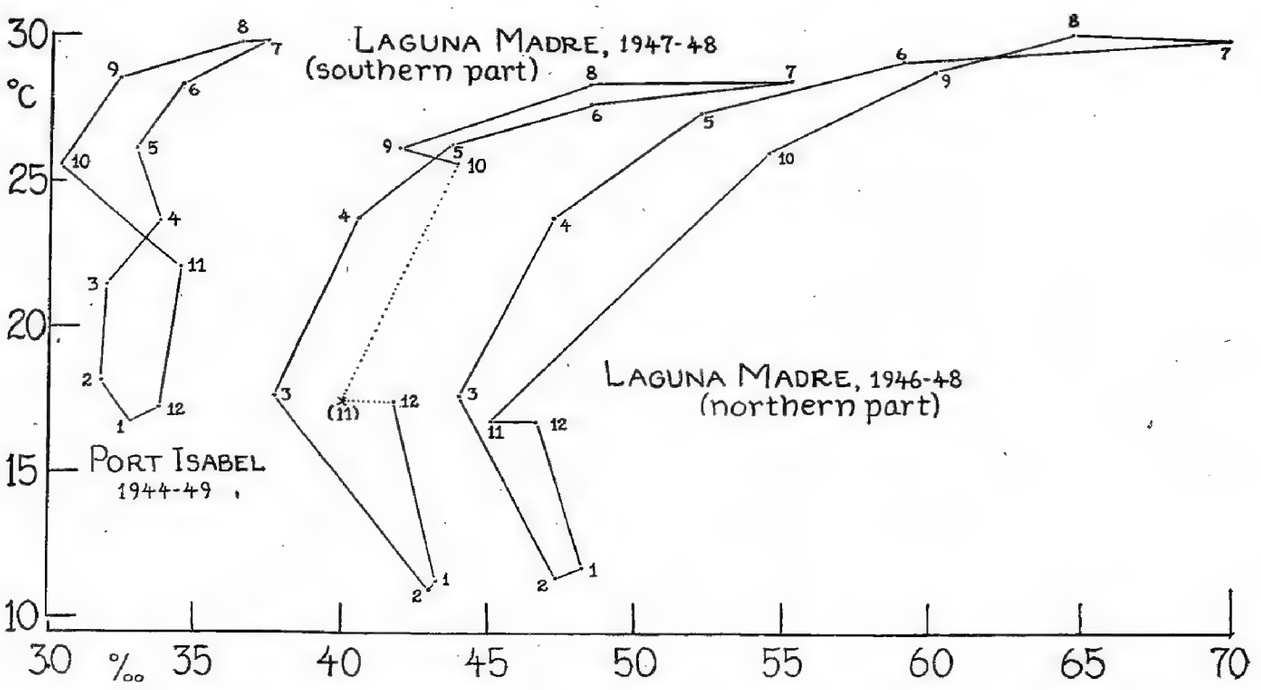

FIGURE 36

Temperature and salinity averages for Port Isabel, and the two parts of the Laguna Madre. Data for Port Isabel from U. S. C. & G. S., 1947, 1949.

are to be found in the access of Corpus Christi Bay waters to the northern Laguna, and the closer connection with the Gulf of Mexico via Brazos Santiago Pass in the southern part of the Laguna. Baffin and Alazan bays are subject to high evaporation and reduced runoff, hence are higher in salinity, on the average, than the adjacent northern arm of the Laguna Madre, although extremely high salinities have been recorded from

the southern pocket of the northern Laguna, just above the shoal region. An analysis of the salinity exchange between the Laguna Madre and Corpus Christi Bay, demonstrated to be primarily a function of the equinoctial tides, has been published by Collier and Hedgpeth (1950). Since the abandonment of the aerial patrol and its incidental gathering of hydrographic data in late 1948 there has been no similar work on the Laguna Madre, and the effects of the opening of the Intracoastal waterway, a channel about 15 feet deep and some 250 feet wide, and of the construction of a solid fill causeway between Padre Island and the mainland just below Corpus Christi, have yet to be studied. At the time of the original studies, the northern Laguna Madre was a somewhat special case of a hypersaline lagoon because of the sill-like bar separating its waters from those of Corpus Christi Bay except during the highest tides.

TABLE 4

Salinity and temperature ranges and means, southern part of Laguna Madre, 1947–48 (Based on four stations occupied by airplane.* For comparable data for northern Laguna, see Collier and Hedgpeth, 1950).

Month	Salinity, o/oo				Temperature °C			
	No. readings	Min.	Max.	Mean	No. readings	Min.	Max.	Mean
Jan.	16	34.5	60.2	43.2	16	4.8	16.5	11.3
Feb.	4	37.1	57.4	43.1	4	7.0	10.5	8.9
Mar.	20	32.4	54.8	37.7	20	17.2	24.6	20.2
Apr.	31	33.8	62.0	40.6	32	17.0	28.0	23.4
May	27	30.4	57.7	43.8	31	24.5	28.0	26.3
June	28	35.1	64.4	48.5	28	25.0	29.5	27.7
July	32	40.8	66.6	55.3	32	27.0	29.5	28.5
Aug.	31	31.1	87.8	48.5	32	27.0	30.4	28.4
Sep.	31	30.9	68.8	42.0	31	21.0	32.0	26.2
Oct.	26	33.9	58.4	44.0	28	24.0	27.8	25.7
Nov.	4	36.8	58.9	50.8	4	15.9	17.8	16.8
Dec.	12	31.3	57.9	41.8	12	8.8	24.5	17.5

* Approximate location of stations indicated on Fig. 48; because of shoals the stations were usually somewhat nearer the western shore of the Laguna. The figures given are combined averages for the period from March 31, 1947 to October 14, 1948.

The Laguna Madre has been, in recent years at least, the major source of fish in Texas. Whether this is entirely due to the peculiar salinity conditions, or is in part a result of industrial pollution in other bays, leaving the Laguna Madre the last unspoiled environment, is undetermined. In view of this, it is unfortunate that so little is still known of the ecology of this area. With the exception of the information on the oysters near Port Isabel which has already been presented, we have no adequate data for these waters. The only locality for which there is some information is the vicinity of Baffin Bay. Between Pt. Peñascal and Point of Rocks, at the entrance to this bay, there occur outcrops of Pleistocene *coquina* and recent serpuloid clumps, the "rocks" memorialized in the Spanish and English names for the two "headlands." Several examples of the serpuloid rock have been examined, without finding any living worms in the tubes, and it may be that the species which made the tubes have been extirpated by increasing salinities (often in excess of 80 o/oo) in the comparatively recent past.[10]

[10] According to notes compiled by W. A. Price (MS, 1950), active growth of these serpuloid reefs amounting to between 1,000 and 2,000 yards was observed between 1875 and 1910. Living serpuloid reefs were observed by Heilprin at Vera Cruz about 60 years ago (Heilprin, 1890), but there seems to have been no subsequent study of this region.

While no living serpulids have been found in various samples from Baffin Bay, two other polychaetes are common in the clumps of tubes, *Nereis pelagica occidentalis*, and *Polydora ligni*. The occurrence of *Nereis* is of particular interest in view of the studies of osmoregulation in *Nereis diversicolor* (Cf. Beadle, 1943b). The serpuloid clumps are adorned with large specimens of *Balanus eburneus*, and thin growths of green algae *Chaetomorpha*. This occurrence of a well-known estuarine species of barnacle in these highly saline waters is paralleled in the Bitter Lakes region of the Suez Canal, where *B. amphitrite* is found (Broch, 1927). Broch considered the barnacles from the Suez Canal a distinct subspecies, proposing the varietal name *denticulata*.[11]

At Riviera Beach, among the sparse green algae on the pilings, and presumably also on the serpuloid clumps, are found two species of amphipods, *Podocerus brasiliensis* and *Grandidierella bonnieroides*. The first of these has been reported from the Suez Canal in salinities up to 49 o/oo; the second is a widely distributed estuarine species. The shores of Baffin Bay are littered with the valves of a small clam, *Anomalocardia cuneimeris*, which is also found in the changing environment of estuarine bays. The specimens fell in a size range from about 6 to 12 mm., although the species attains a size of 17 mm. in less saline waters (Table 5). This smaller size range in high salinities was discussed, in reference to *Neritina virginea*, by Andrews (1940). A cast taken with a small plankton net on May 21, 1951 near Loyola Beach contained a well known brackish water copepod, *Acartia tonsa*. The most abundant fish in this region are cyprinodonts and an atherinid, *Menidia beryllina*.

TABLE 5

Length-frequencies, *Anomalocardia cuneimeris*

Length, mm.	Loyola Beach, Laguna Madre, May 21, 1951	Key Largo, Fla. 1929	Length, mm.	Loyola Beach, Laguna Madre, May 21, 1951	Key Largo, Fla. 1929
3	4	---	13	1	3
4	11	---	14	---	2
5	13	1	15	---	1
6	27	9	16	---	2
7	80	13	17	---	1
8	57	24	---	---	---
9	53	26	22	---	1
10	17	22	---	---	---
11	9	16	25	---	1
12	4	14	Totals:	276	136

The occurrence of these animals, all widely distributed euryhaline forms, comprises additional evidence in favor of Fox's (1927) observation that animals living in brine pools occur also in waters of low salinity. Most of these organisms are also absent from the sea, although the factors preventing their occurrence in the sea may be ecological (*e.g.*, competition) rather than physical or physiological. As in the bays, there is a reduction in the number of species of both plants and animals as compared with the sea.

A remarkable feature of the fauna of Baffin Bay is the occurrence of swarms of a medusa, *Phortis* sp., collected in May, 1951, by M. D. Burkenroad; earlier collections

[11] Variations in barnacles in peculiar environments are the rule; a similar case is that of the specimens of *Balanus amphitrite* from Siwa Oasis (nearly 200 miles from the sea, in a chlorinity of 24.8 o/oo!) which may be similar to the Suez Canal subspecies which in turn seem to be the same as Darwin's variety *communis* (Nilsson-Cantell, 1949).

of this or a similar medusa, without data, were made by J. C. Cross. A similar medusa, belonging to the closely related genus *Eucheilota*, was reported by Browne (1927) from the vicinity of Kabret in the Suez Canal, in salinities of 40–50 o/oo. The collections in the Canal were made during November, and there is no account of its occurrence during the warm season when it might be expected to occur in larger numbers.

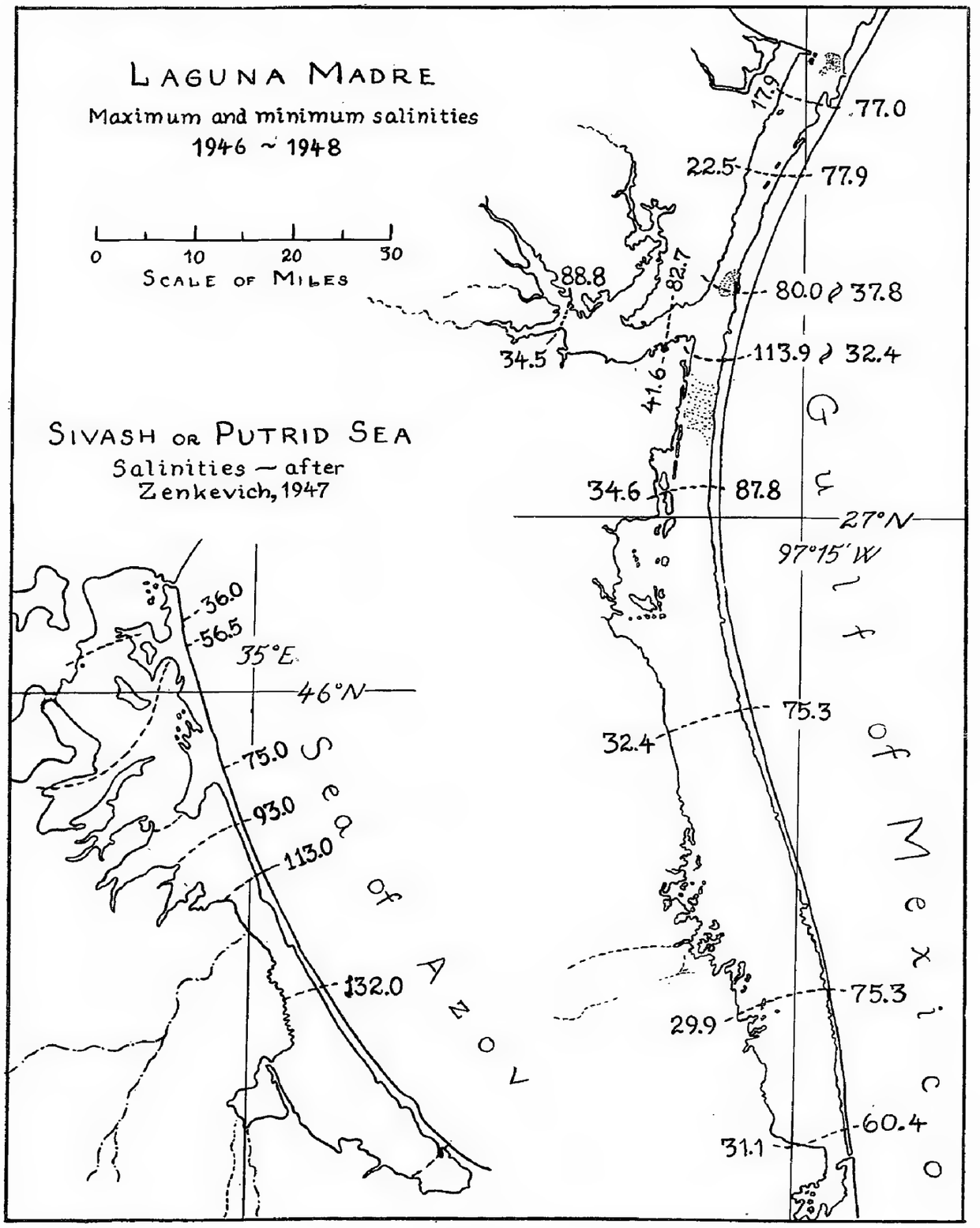

FIGURE 37

The Laguna Madre and the Sivash, to the same scale (the large western arm of the Sivash is omitted), with salinity characteristics.

Lacking from this admittedly preliminary catalogue of the fauna of Baffin Bay is the brine shrimp, *Artemia*. It seems probable that there are too many fish in Baffin Bay for *Artemia*. Fox, in an editorial note to Beadle's paper (1943b), suggests that Artemia's distribution is limited by its inability to defend itself from predators.

There are certain features shared in common by the Sivash and the Laguna Madre, although their faunas are much different. The fauna of the Sivash includes *Artemia* and an array of forms from the Sea of Azov and the Black Sea as well as *Ephydra* and *Chironomus*. (These may possibly occur in the Laguna Madre). The ubiquitous mullet, *Mugil cephalus*, occurs in the Sivash and in the Suez Canal as well as in the Laguna Madre. The Sivash is about 1,000 square miles in area as against the Laguna Madre's approximately 900 square miles; both are shallow, subject to high summer temperatures and evaporation (Figure 37). Freezes occur in both the Sivash and the Laguna, but are more severe in the Sivash since that body of water freezes over in winter.[12] Both are productive fishing areas, with relatively frequent mass mortalities in summer. In view of these similarities, it is interesting to note that the same remedy for relieving the hypersaline conditions has been proposed, namely the cutting of a pass or channel across the lower end of the bar to admit less saline waters into the affected regions. Zenkevich (1947b) mentions the recommendation of such a project, and according to Dr. N. T. Mirov (personal communication) a previous attempt to alleviate the salinity of the Sivash by such an artificial channel was a failure. The history of such attempts in Texas has been no more distinguished (Gunter, 1945b).

Basic data upon which to base comparisons of the chemical composition of various hypersaline environments are inadequate, and the information gathered together in Table 6 is merely suggestive. The necessary information for the Sivash is unobtainable

TABLE 6

Composition, by Per Cent, of Certain Natural Waters
(Compiled from various sources)

	Sea Water*	Laguna Madre†	Suez Canal‡	Gulf of Kara Bugaz§
Cl	55.04	60.5	55.59	53.32
Br	-----	-----	0.14	0.06
SO_4	7.68	2.15	7.67	17.69
CO_3	0.41§	0.23	0.01	-----
Na	30.62	31.4	31.21	11.51
K	1.19	-----	0.64	1.83
Rb	-----	-----	0.01	0.06
Ca	1.15	0.93	1.05	-----
Mg	3.69	3.68	3.64	15.83
o/oo	35.0	64.05	51.03	285.0

* From Rankama and Sahana, 1950.
† From data in Collier and Hedgpeth, 1950.
‡ From Clarke, 1924.
§ as HCO_3 —.

in this country, although data on many strange environments were gathered together in Clarke's (1924) compilation. As can be seen from the table, the Gulf of Kara Bugaz is a peculiar body of water, in no way comparable with such regions as the Laguna Madre.

[12] I have seen no map showing depths in the Sivash; this information comes from A. D. Bajkov, who informed me, somewhat testily, that an artillery battery under his command was outflanked by the Bolsheviks by crossing on the ice. According to Zenkevich (1947b) the greatest depth is 3.2 meters.

5. The Sand Beach

The appeal of beaches to geologists and engineers has not been matched by a comparable interest on the part of biologists. There are few places in the world where the fauna of a sand beach is of sufficient importance to inspire investigations of an economic character comparable to those represented by the extensive literature by harbor and breakwater engineers on the movements of sand and other aspects of the physical regime of beaches. In the bibliography by Haferkorn (1929), several hundred titles are listed; the more recent literature on sand characteristics, beach processes and the like is listed in the various issues of the Bulletin of the Beach Erosion Board.

A search of ecological literature reveals but four studies on the biota of sand beaches in eastern North America: the pioneer study by Davenport (1903) on the Cold Spring Harbor sand spit, that of Newcombe (1935) in the St. Andrew's region of New Brunswick, the more extensive work of Pearse, Humm, and Wharton (1942) on the beaches at Beaufort, North Carolina, and the brief faunistic note by LaFleur (1941) on the beach at Grand Isle, Louisiana. Davenport's paper, somehow overlooked by most subsequent students of sandy beaches, is nevertheless considered worthy of special mention by Allee *et al.* (1949, p. 48), and it does show more concern for the fundamental problems of environmental adaptation than any of the others.

On the Pacific Coast of America, the only general ecological study to come to notice is that by H. W. and M. Koepcke (1952) of the food chains on the sandy beach of Peru.

Of the European work on sand faunas, a few titles apply to the restricted problem of the sandy beach, as opposed to more general studies of sandy tidal flats or particular organisms. Foremost of these are the recent summaries by Yonge (1949b, Ch. 15; 1950). Mortensen's (1922) observations on the sand fauna of Danish beaches and other areas visited by him is a generally overlooked but useful account. Although in Danish, it is provided with an extended English resumé. In this paper the two fundamental environmental divisions of the sandy shore are well summarized:

> The fauna of sandy beaches may be naturally divided into two main regions, the fore-shore zone and the tidal zone. The marine species inhabiting the foreshore are adapted to living on dry land, but can stand being washed over by the sea; those of the tidal zone remain true marine animals, but can stand lying dry during ebb-tide. The foreshore forms partly follow the water outwards with the ebb-tide and retreat for the rising flood, always keeping above the water; they are mostly fast moving animals, which makes it possible for them as a rule to avoid being washed over by the waves. The free swimming forms of the tidal zone keep below the water; if left by the retreating waves they quickly burrow themselves into the sand, remaining here until the water rises and sets them free again. The sedentary forms simply retreat into the sand during ebb-tide (p. 53).

Schulz (1937), in his study of the sand fauna of an area on Amrum Island (one of the North Friesians), observed the arrangement of life in zones somewhat similar to those of a rocky beach. This seems to be the first serious effort to correlate tidal levels and the biota of a sand beach. The most recent European contribution to the study of the sand beach as a biotic environment is that of Caspers (1951a) on the sandy shores of Bulgaria. In the hierarchy of ecological terminology set up by this

author, the sand beach is the "*Orchestia variation*" of the "*Pachygrapsus-biocoenosis*" of the shore community (Ufer Gemeinschaft).

A beachcomber who visits the beaches of Texas notices first, the very gentle slope of these beaches, and then, the extremely fine sand of which they are composed. The sands of some beaches of California and Florida seem to consist of small gravel in contrast. According to Bullard (1942), the sands of Texas beaches are very highly sorted and consist principally of 1/8 and 1/16 mm. sizes (0.125–0.062 mm.). Emery and Foster (1942) give the median diameter of sand at El Segundo Beach, California, as between 0.22–0.33 mm., and of the Scripps Beach at La Jolla as 0.18 mm. The fine, naturally sorted sand of the northwestern Gulf Coast is capable of a much higher moisture content than coarser beach sands because of the more numerous spaces between grains. Bruce (1928) gives a water content of 42–44% for fine graded sand of 0.15–0.19 mm. range as contrasted with 20% for the natural ungraded sand of the Port Erin beach (ranging up to .54 mm.). These are saturation figures; fine sand is also subject to higher evaporation rates because of the increased capillary action. Sand from a sample above the water line at Port Aransas, subject to several hours evaporation, was found to have a moisture content of about 24%.

This fine sand offers fewer large spaces for sub-macroscopic animals such as copepods, tardigrades and small worms, and such organisms have not yet been found in Texas beaches. There is, however, an abundant bacterial flora, especially near the passes. This abundance, which makes the waters of the shore zone of the Gulf of Mexico "veritable marine gardens" is attributed by Zobell (MS) to the high content of organic matter and suspended solids in the waters.

Backshore and Foreshore

Although an elaborate terminology has been developed for beaches (*cf.* Shepard, 1948, fig. 33), several of the features found on steeper, tidal beaches are not well developed on the gently sloping beaches of the Texas and Louisiana coasts. Berms and beach scarps are almost imperceptible in many places. The foreshore, or area between tide lines, may be as much as 150 feet wide, and the slope between 1:70 and 7:80. The backshore, between high tide line and the "coast line" varies from 50 to several hundred feet, and is marked by a slight change in slope at the crest of the beach. This crest, indicated by drift and windrows of shells, is comparable to the berm crest of a more elaborately developed beach. The coast line proper on such a beach is the line defined by the seaward bases of comparatively stable dunes. This line of dunes overlies the youngest, or outermost, beach ridge. From the crest of the beach, where there is a change in slope, to the dune line, is the dry sand surface which is the chief source of eolian sand for the dunes. Through the action of wind and leaching out of fine particles by water and the segregation of shells above this crest, an eolian pavement is formed. Below the crest, on the steeper slope, cusps or sawtoothed indentations are formed by storm action (other storms may smooth out the beach, however). These cusps run down to the water line, and their teeth may be 100 to 200, or 400 feet apart (as in giant cusps).

There are few sandy beaches on the Louisiana coast. Such beaches as occur are narrower, and end in a coast line consisting of a low, wave-cut bank a few feet high,

or a line of low dunes. Most of the Louisiana shore line is an abrupt transition between sea and marshland, and results in a beach consisting of mud or small dissected blocks of marshy sod (see Russell *et al.*, 1935). The principal sand beaches of Louisiana are at Cameron, near Calcasieu Pass, the "front beach" of Grand Isle, and the beaches of the Chandeleur arc. The Grand Isle beach, 7.5 miles long, is described in some detail by Brown *et al.* (1936).

Offshore

The slope of the offshore beach on the coast of Texas is 1 or 2%, although it may be steeper in some places. The average slope of the beach at Grand Isle was determined by Brown *et al.* (1936) as 1:48. These gradual slopes, combined with the narrow tidal ranges, provide ideal conditions for the development of shallow bars in the beach parallel to the shore line. The outermost, or largest, bar occurs on most Texas beaches at about 1,000 feet from shore. Its crest is 6–8 feet below mean low water, and the accompanying trough is 12–15 feet deep. The inner bars, usually two, are closer to shore and nearer to each other than to the outer bar, and are less than six feet below mean low water. The height and position of the outer bar makes the broad beach dangerous for fishing boats, even in comparatively calm water. Some idea of the height and position of these bars can be gained from the schematic profile of the Mustang Island beach at Port Aransas (Figure 38). The bars are clearly indicated from the beach by the breaker lines, and show up in aerial photographs either as breaker lines or, in clear water on calm days, as light streaks.

These bars have been variously called offshore bars or submarine bars. Characteristically there is a series of bars—two or three parallel rows with troughs between them. They occur on many coasts, and are not limited to tideless seas as suggested by King and Williams (1949) although they are best developed in such regions. These bars and troughs also occur in Lake Michigan, where they are known as "low and ball." Since the term "offshore bar" has wider application in the literature in reference to the barrier beach ("barrier island" of Price's terminology, 1951), or outer island cordons of such coasts as those of Texas and the Carolinas, Shepard (1950) has proposed the terms "longshore bar" and "longshore trough."[13] There is no set length for these bars. On such a coast as Texas the bars may be several hundred yards or a mile long. On coasts with a large tidal range the bars are short, interrupted by drainage channels; the "ridge and runnel" bars of King and Williams.

There are places along the apparently monotonous beaches of Texas which seem to be more favorable than most of the shore for the gathering of shells and other curiosa of the sea. Even after heavy storms the material from the bottom is cast up unevenly along the shore. A typical area of this sort occurs about five miles south of Port Aransas on Mustang Island, and there is another a mile or so south of the Pass near the fishing pier. This localized concentration of larger objects has been observed on the Fire Island beach at Long Island by Rosalsky (1950), who attributes it to a gentler slope of the beach at the locality, which reduces the velocity of the backwash, thereby stranding the objects.

[13] For further discussion of terminology, see Shepard, 1952. For a comprehensive account of shore lines, on a world-wide basis, see Valentin (1951), especially his excellent map.

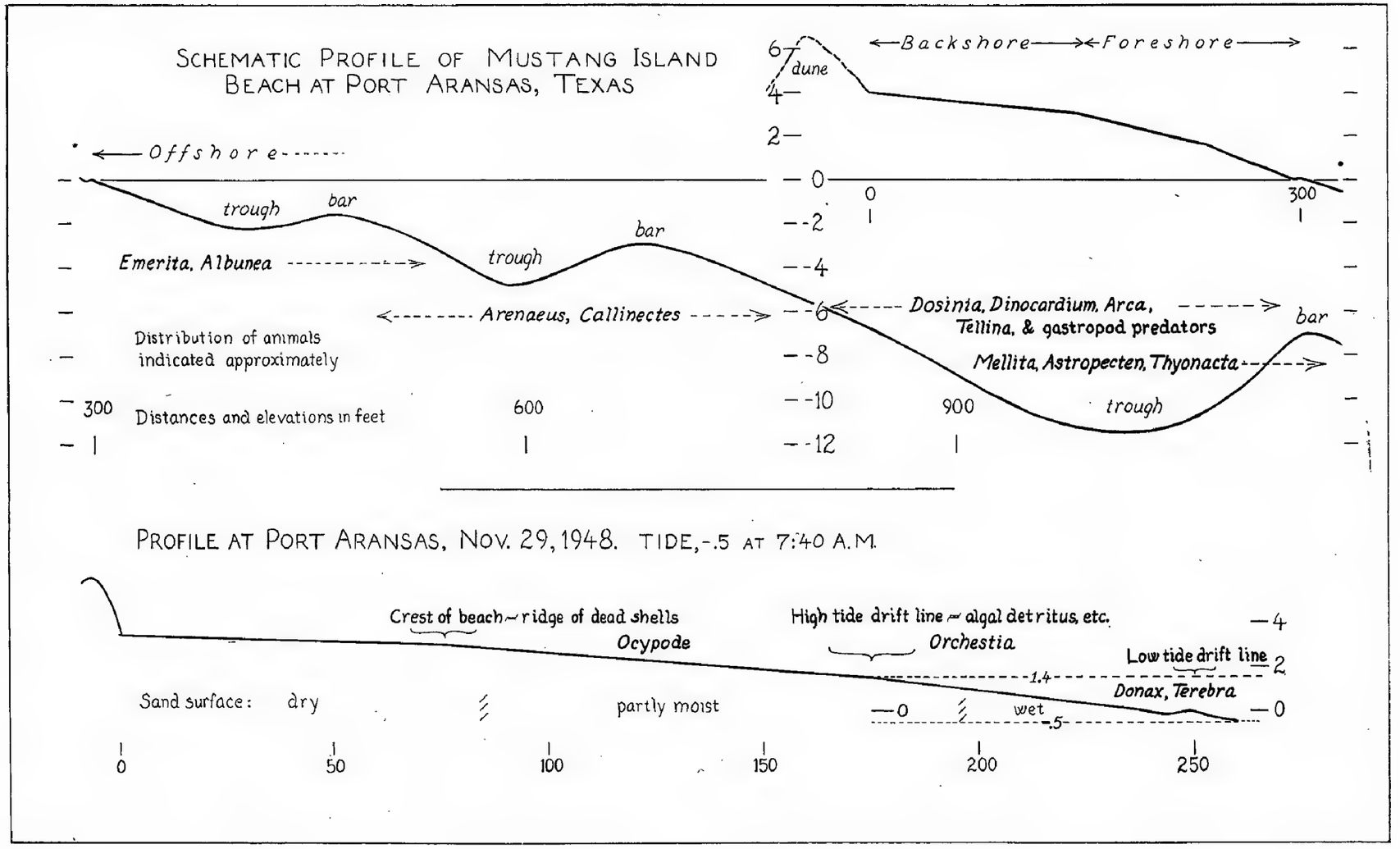

FIGURE 38

Schematic profile of beach at Port Aransas, Texas, showing bars and approximate distribution of characteristic organisms, together with observed profile of beach above low water on November 28, 1948.

To be distinguished from these minor, local concentrations, which may be as much a reflection of winnowing action by waves as of differences in slope, are the Little Shell and Big Shell beaches on Padre Island near 27° N. This region, where the shore line makes its sharpest curve and thus changes direction in relation to the prevailing winds, is the meeting place of the longshore currents. Here the beach is steeper, the sand consists of a lower percentage of resistant components such as zircon, garnet and tourmaline (Bullard, 1942), and in some places is composed principally of shells. This region is often impassable to automobiles.

A transitory formation of sandy beaches is a small flat bar near the water line, which forms a shallow tide pool behind it. This bar, termed "swash bar" by King and Williams, is formed by the action of wave swash shoreward of the break point of the waves over the innermost bar. On the Gulf Coast, where tidal ranges are slight and the innermost longshore bar remains covered even at low tides, these swash bars are often comparatively high on the beach. Smaller swash bars are observed on the bay beaches. Swash formations and other minor beach forms are described by Rosalsky (1949), who proposes, on Shepard's suggestion, the term "overwash pool" for the larger pools formed well up on the beach after exceptionally high tides.

Life on the Beach

The most conspicuous invertebrate living on this apparently barren beach is the ghost crab, *Ocypode albicans*. Yellowish gray in color, it is almost invisible when motionless except for its brownish black eyes held aloft on erect stalks. It is capable of rapid bursts of speed up to thirty miles per hour for short distances, and of startling changes in direction at this speed. While usually nocturnal or crepuscular in habit, the ghost crab is sometimes encountered out of its burrow in full daylight. The adults roam widely, from the water line well back into the dunes, feeding principally on carrion. If the food is too large to be carried back to the burrow, the crab will dig a burrow beneath its food supply. Dozens of crabs were routed out of such burrows beneath the decayed remains of a small whale. The burrow, about two inches in diameter, is a sharply slanted, almost vertical shaft two to four feet deep, usually well above the high tide line, but leading to damp sand. During the daytime the burrow is plugged and is not easily found. The crabs may live without water as long as 48 hours (Cowles, 1908), but must return to the water's edge to moisten their gills. This is an operation performed with cautious haste. The crab does not enter the water unless chased there by some predator, but dips in one side at a time, keeping half its legs on dry land, ready to dart up the beach at the approach of an enemy from the sea. The best way to observe these alert and wary animals is to spend a night on the beach, or, like Milne and Milne (1946), to domesticate them. This crab occurs on sandy beaches from Rhode Island to Santa Catherina, Brazil, and has ecologically equivalent congeners on the Pacific side of the continent, *O. occidentalis* and *O. guadichaudi*. This latter species is considered to be the key animal in the food chains of the sandy beach of Peru by the Koepckes (1952). Young ghost crabs, of carapace widths of ½ to ¾ inch, have been observed in the swash lagoons near Port Aransas in August.

Farther down the beach, usually in association with drifts of algae, various amphipods occur. Three species of these beach hoppers are represented: *Orchestia grillus, O. platensis,* and *Talorchestia longicornis*. Of these, *O. platensis* is the more

common. Like most of the amphipod fauna of the Gulf of Mexico, these are widely distributed species which range from sub-boreal to tropical regions. While these small animals may be numerous at times, and serve an important function in the economy of the beach, their presence is not always obvious. Many of the holes in the sand which are at first mistaken for their burrows turn out to be air holes; the author has dug up many of these without discovering signs of life. Emery (1945) did not find air entrapment features, *e.g.*, blow holes and small domes, in the fine sand of Galveston Beach, but they often occur in the swash zone.

The larger fauna of the intertidal region of Gulf beaches is sparse by Pacific Coast standards—the millions of burrowing *Emerita* are represented by an occasional one or by isolated small colonies. LaFleur (1940) comments on the rarity of *Emerita* on the Grand Isle beach. The populations in the vicinity of Beaufort are not much larger. The species found on the Texas and Louisiana coasts is *Emerita portoricensis*, and it may not be as successful as *E. talpoida* of the middle Atlantic or *E. analoga* of the Pacific beaches. *Emerita* is an animal which feeds on wave wash detritus and plankton, and on beaches where wave action and tidal ranges are pronounced, moves up and down the beach. This habit is shared by the bivalve *Donax*, and the "butterfly clam" or coquina. *Donax* is more common on Texas beaches than *Emerita*, and occurs in colonies of several thousand to perhaps millions of individuals. In front of incoming waves of the rising tide they periodically pop out on the sand and are washed up on the beach. As the wave recedes, they dig their way back into the sand with a rapid, rocking action. On a falling tide, they rise out of the sand on the backwash.[14] When an animal attains a firm purchase in the sand with its foot, it swings the shell upright and disappears downward. When several hundred clams are digging in this manner, the beach seems to be alive or "jumping." A small toxoglossid, *Terebra*, preys upon *Donax*, and is occasionally found in groups like its prey, burrowing into the sand between waves. A number of species of both these genera have been listed as occurring along the Texas coast, and those assigned to *Donax*, in particular, seem to be in need of more critical systematic work. There are at least two common species.

Worms are not usually abundant between tide marks, perhaps because the tidal fluctuations, while slight, are prolonged. It seems possible that the formation of large beach cusps by storms would inhibit the development of large communities of worms since such redistribution of sand would cover up beds. An occasional nereid or lumbrinereid here and there comprises most of the worm fauna of the outer beach. At some times, however, worms occur on the beach in vast numbers. One of the species is *Nerine agilis*, which forms large beds in the vicinity of Beaufort, North Carolina. On sheltered bay shores worms are more abundant, but particularly so in areas below the lowest water, or where exposure occurs only a few times a year.

The comparatively low populations of tidal zone forms on Gulf coast beaches as contrasted with the populations observed on Danish and tropical beaches by Mortensen (1922) and the species mass of *Emerita*, *Tivela* and *Thorocophelia* (McConnaughey and Fox, 1949) on the cold temperate California coast may be

[14] Observations on relation of wave and tide to emergence of *Donax* courtesy M. D. Burkenroad. The papers on tidal rhythmic migration of a Japanese species (Mori, S., in *Dobutsugaku Zasshi*, Vol. 50 [1938] and Vol. 59 [1950] have not been seen.

as much an expression of the extraordinarily wide annual temperature range on the Gulf shore as of the peculiar tidal conditions. Since low shore temperatures in winter months along northern Gulf beaches are accompanied by northers blowing offshore, the available food is probably blown off into the water or buried under the dry sand of the higher beach. Few intertidal organisms can withstand exposure to such a temperature range as 4–5 to 30° C. (air), especially when the low exposures are more often than not the result of sudden drops of 10° C. induced by the northers, coincident with a sustained depression in tidal levels and drying out of the beach surface.

Little is known of the precise habitats of most of the animals that live on the beach between low tide and the lower limits of the sand beach. The portunid crabs *Callinectes* and *Arenaeus* often take up stations along the plunge line, and *C. sapidus* spawns in the waters of the innermost beach trough from late March or early April to well into late summer at Port Aransas. Between the shore and the second bar, the region accessible to beach seining, such animals as *Albunea gibbesii* and *Callianassa* are occasionally found. The latter is more common than apparent, but is difficult to dig out of its burrow. In the third trough, accessible on calm days to small boats trawling for bait shrimp, the keyhole urchin, *Mellita quinquesperforata* is common, sometimes abundant. The sand stars of the genus *Astropecten* (at least two species) are not quite as numerous, but far from rare. The holothurians, *Thyone briareus* and *Thyonactis sabanallensis*, are common, to judge from their numbers cast up by storms, and their undamaged condition indicates that they did not come very far. When the action of bars in storms is remembered, *i.e.*, the shoreward movement and obliteration of the inner bars and seaward migration of the outer bar, it seems reasonable to conclude that these and other burrowing organisms occasionally found intact on the beach came from the longshore troughs. Often live mollusks are found in beach drift with the holothurians, including *Arca* (or *Anadara*), *Dinocardium robustum*, *Phalium granulatum*, and *Oliva sayana*.

The beach troughs of Louisiana are evidently less favorable for bottom invertebrates. The keyhole urchin and the sand stars are considered rare in the vicinity of Grand Isle; large holothurians are scarce. (*Thyone briareus* was reported cast up on the Cameron beach by Cary, 1906b), and the murices have not been collected at Grand Isle, at least according to Behre's (1950) faunal list. This is in part a reflection of the lower salinity conditions—the occurrence of *Luidia clathrata* in the region is used as an indicator of high salinities—but it is also a result of the greater silt content of the waters and more active sedimentation along the Louisiana coast. Kellogg (1905) described the soft mud trapped in the troughs near the shore at Cameron. Entrapments of sediments by the bars occur immediately after heavy runoff, and while the mud may be disposed of in a few weeks by natural beach processes, the abrupt change in the environment makes it unfavorable for such organisms as echinoderms and deposit and filter feeding lamellibranchs. Not all bivalves share the oyster's ability to endure periods of excessive sedimentation.

The most conspicuous feature of the Texas beach, from the beachcomber's viewpoint, is the variety of shells cast up on the sands. Most of these are bivalves: *Dinocardium*, *Arca*, *Anadara*, *Dosinia*, *Pecten*, *Tellina*, *Anatina* and several other genera. Gastropods include *Phalium*, *Busycon*, *Oliva*, and *Murex* among the larger

shells. These shells occur in windrows after storms, indicating the existence of an extensive economy of bivalves and gastropod predators; many of the bivalves, especially the arcas, *Dosinia* and *Tellina,* are neatly drilled by some predaceous snail.

Much more has been written on the functional adaptations of sand dwelling animals than upon their populations as related to the environmental factors of the beach. One of the few papers in the latter category is that by Johnson (1940) on the dispersal of larvae of *Emerita* by shore currents. The adaptations of burrowing crabs to a psammophilous life, especially the structural modifications subservient to maintaining respiratory currents, were described by Garstang (1897), and subsequent work on this problem has added details (*e.g.*, Pearse, Humm and Wharton, 1942). Snodgrass (1952) has studied the structural adaptations of *Emerita* and related sand crabs in detail, pointing out that *Emerita* is unique among Crustacea in its manner of filter feeding by the use of antennae. A treatment of structural adaptations in the mollusca, especially as related to feeding, will be found in the papers of Yonge, particularly that on the Tellinacea (1949a), which includes a discussion of representatives of such characteristic Gulf coast genera as *Donax* and *Tellina.*

6. The Jetties

The monotonous sandy and muddy beaches of the northwestern Gulf coast have been interrupted by the construction of jetties at those passes important to navigation. Two of the passes of the Mississippi, South Pass and Southwest Pass, have large jetties. There is a small pair of jetties at Calcasieu Pass, near Cameron, and there are five pairs of jetties on the Texas coast, at Sabine, Galveston, Freeport, Port Aransas and Port Isabel (Figure 35). Brief mention of the fauna of the Cameron jetties was made by Cary (1906a), but the jetties of the delta have not been studied by biologists. The general characteristics and biota of the Texas jetties have been described by Whitten, Rosene and Hedgpeth (1950).

The jetties have been constructed by covering a fill of rubble and small stones with large quarry blocks, forming a long wall which is triangular in cross section. This structure is 3 to 5 feet above mean low water, and, in easily accessible localities, has been surmounted by a concrete cap forming a broad walk about 6½ or 7 feet above low water. The jetties vary in length from a few hundred yards (Freeport) to 3.5 miles at Galveston. They lie athwart the shore currents and are subject to the piling of sand about their bases, reducing the area of available rocky substrate for organisms. During storms and in the spring, waves break over them, promoting a growth of slippery green algae and rendering them dangerous to walk on. The jetties are the favorite posts of anglers, who line up on them by the hundreds when the word has been passed that the fish are biting. This practice results in a fairly steady supply of fish scraps and bait shrimp for the crabs and isopods which frequent the upper parts of the jetties at night.

In addition to being subject to wave action across their crests and to shifting sand about their bases, the jetties are in localities where broad variations in salinity are the rule. This combination of environmental factors has limited colonization to hardy forms capable of withstanding wave shock, sudden variations in salinity and the low winter temperatures of the region. While the life on the jetties is sparse, it is of par-

ticular interest since it represents a colonization of an environment which has been available less than a hundred years. The foundations of Fort Livingston, on the east side of Barataria Pass, are more than a century old, but the walls are barren except for a few barnacles. Perhaps the salinity range at Barataria Pass is too great.

Several of the animals living on Texas jetties do not occur on sandy or muddy shores. The most conspicuous of these is the pulmonate limpet, *Siphonaria pectinata,* which was apparently unknown to the older naturalists like Strecker and Mitchell, who collected persistently along the coast of Texas. No *Siphonaria,* or any other limpet, is mentioned in Mitchell's detailed list (1894), but *S. pectinata* is now common on jetties from Brazos Santiago (Port Isabel) to Galveston. It is possible that *Siphonaria* has made its way to Texas in the last 50 years. It is Atlantic Tethyan in distribution, occurring in the Antilles and at Vera Cruz and southern Florida, in the Mediterranean and on the eastern Atlantic coast from Portugal to Cameron. There is also a record from Chile (Hubendick, 1946, 1950).

Another West Indian immigrant is *Littorina ziczac* (also not collected by Mitchell), the characteristic littorine of Texas jetties. A splash zone barnacle, *Chthamalus fragilis,* is another organism not found on the natural shores. This trio occurs not only on the outer jetties, but also on the harbor breakwaters inside the bays, *e.g.* at Rockport and Corpus Christi, indicating a broad range of tolerance to variations in salinity. These three animals are also capable of surviving hours, and occasionally days, of exposure to air, and thrive best in the upper zones. Their essential requirement is evidently the rocky substrate. The algae of the jetties are more conspicuous than the animals, although the flora is not abundant as compared with that of cold temperate regions. This flora is predominantly southern in relationships (Taylor, 1941). The plants are small, growing in scattered tufts and narrow zones or belts. The greens, *Enteromorpha* and *Cladophora,* which grow at the higher levels, die off in winter when seasonal tide levels are lower.

While the zonation on the jetties is at first glance inconspicuous and somewhat variable with the season, it is nevertheless well defined within narrow limits (Figure 39). The uppermost zone, consisting principally of scattered barnacles *(Chthamalus), Siphonaria,* and *Littorina ziczac,* begins about 3.5 feet above the low tide line (or 4.5 feet if measured from the extreme January-February lows), and is about two feet wide, on the concrete piling and the inner jetty near the dock at Port Aransas. *Siphonaria* and littorines are scarce on the piling, perhaps because the substrate is too smooth; the littorines characteristically nestle in cracks and holes. Seaward, toward the greater wave action, this zone broadens until at the end of the jetty it occupies the rocks and wall up to 6–7 feet above sea level. The thickest band of barnacles occurs between three and two feet above mean low water, and there is a sparsely occupied region below this zone. This in turn is followed, about 6–8 inches above mean low water, by a thick growth of *Ulva,* and occasional bushy red algae. On the piles and near shore this zone is occupied by oysters and *Thais*; the oysters are absent farther out on the jetty. The *Ulva* zone is only about six inches wide. Between the *Ulva* and about half a foot below mean low water, that is, about average low tide line, is a zone about a foot wide occupied by various species of red algae, *Gracilaria, Gelidium,* etc., which is sharply separated from the next zone, whose characteristic inhabitant is the brown alga *Padina Vickersae.* Here also occur a few anemones *(Bunodosoma)* and urchins *(Arbacia),* but these are more common lower down. This *Padina* zone is about a

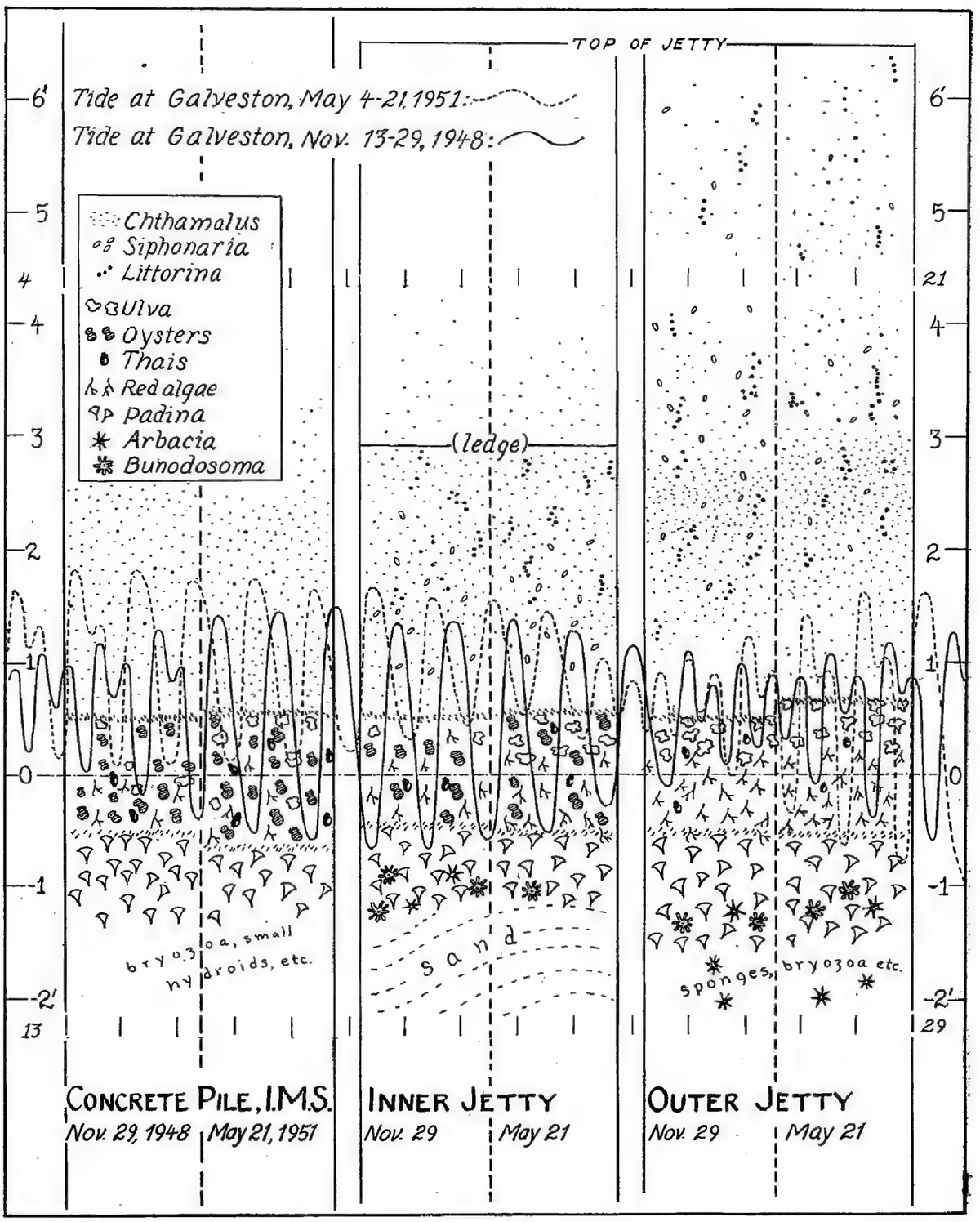

FIGURE 39

Diagram representing zonation on concrete piling and jetties at Port Aransas, as observed on November 29, 1948, and May 21, 1951, with the predicted tide curves for the two-week period preceding observations superimposed.

foot wide—usually less—and is exposed only during the very lowest tides, which usually occur in January and February. Below the *Padina* occur the characteristic subtidal organisms, the bryozoa, sponges and hydroids. Especially conspicuous at the end of the jetty are the bright patches of red, yellow, and purple encrusting sponges.

In spring the upper limits of the zones are slightly higher than they are in autumn, but not conspicuously so. There is a pronounced diurnal movement of the littorines. During the day these small black snails gather along crevices and in cavities, or are widely distributed over the smoother rocks. At night they follow the water line, and in early morning form a conspicuous narrow belt just above the water line. Two motile arthropods, *Pachygrapsus transversus* and *Ligia exotica,* move up and down with the changes in water level, usually staying just above the water line. It is to be noted that while the lower zones maintain approximately the same level from the pier to the end of the jetty, the upper zones increase in breadth with wave action. This suggests tidal control for the lower zones and wave action for the upper zones.

This description applies only to the jetty at Port Aransas. There are some differences in the faunal composition at Port Isabel and Galveston which indicate a transition along the Texas coast between West Indian and middle Atlantic faunas. A common, though not conspicuous anemone on the Brazos Santiago jetty, *Anthopleura krebsi,* is, if it does occur at all, very rare at Port Aransas. Most conspicuous is the absence of mussels at Brazos Santiago and Port Aransas. Although common on the Galveston and Freeport jetties, *Brachidontes recurvus* is evidently excluded from the more southern jetties because it does not tolerate the higher salinities of these regions, or is too heavily attacked by *Thais.* In the Aransas area this mussel does not live in the lower part of Aransas Bay, and in "normal" years mussels on oysters transplanted from Copano Bay die off in Aransas Bay in a few months. The suggestion that certain faunal elements, especially oysters and mussels, are displaced shoreward on the jetties from north to south (Whitten, Rosene and Hedgpeth, 1950), has been received with skepticism by Pulley (1952). In view of the faunal changes which have occurred along the Texas coast in the last few years, this problem requires examination. However, this is substantially the distribution of oysters in relation to the coast line from Marsh Island to Port Isabel.

The recent investigations of the zonation in the Florida Keys and at Beaufort by Dr. and Mrs. Stephenson (1950a, 1950b), indicate some interesting differences in the zonal patterns of these various localities (Figure 40). The "black zone" which the Stephensons found just above the *Chthamalus* was not observed at Port Aransas. The relation of the *Chthamalus* zone to extreme high water is the same at all three localities, that is, the extreme high water line is at about the middle or lower third of the *Chthamalus* zone. This zone is much broader at Port Aransas, at least on the end of the jetty, which is to be expected from the greater wave action there. The lower, almost uninhabited part of the *Chthamalus* zone at Port Aransas is evidently equivalent to the *Spiroglyphus* sub-zone on the West Summerland sea wall. That is, a zone has been displaced upward, while the next zone down has not moved up to fill the gap. It would appear that the biota which should occupy the intervening region is limited from Port Aransas by other factors. If *Spiroglyphus* could live at Port Aransas, it would probably occupy this "sparse zone." The oyster-*Ulva* zone at Port Aransas is proportionately lower than at Beaufort, and the Port Aransas *Padina* zone can be equated with the mussel zone at Beaufort. The most significant difference between these various

patterns is the relation of the zones to tide zero (mean low water). At Port Aransas the zones are relatively much lower, an indication, in all probability, of the pronounced seasonal difference in sea level at Port Aransas. A similar depression of littoral communities toward the south along the California coast was observed by Gislén (1944), who attributes this lowering to increased insolation, lower humidity and tidal exposure at unfavorable hours of the day. On the Texas coast insolation (especially as associated with seasonal differences in sea level) is probably an important factor, but humidity and diurnal tidal differences are less marked between Beaufort and Port Aransas than between Pacific Grove and Enseñada.

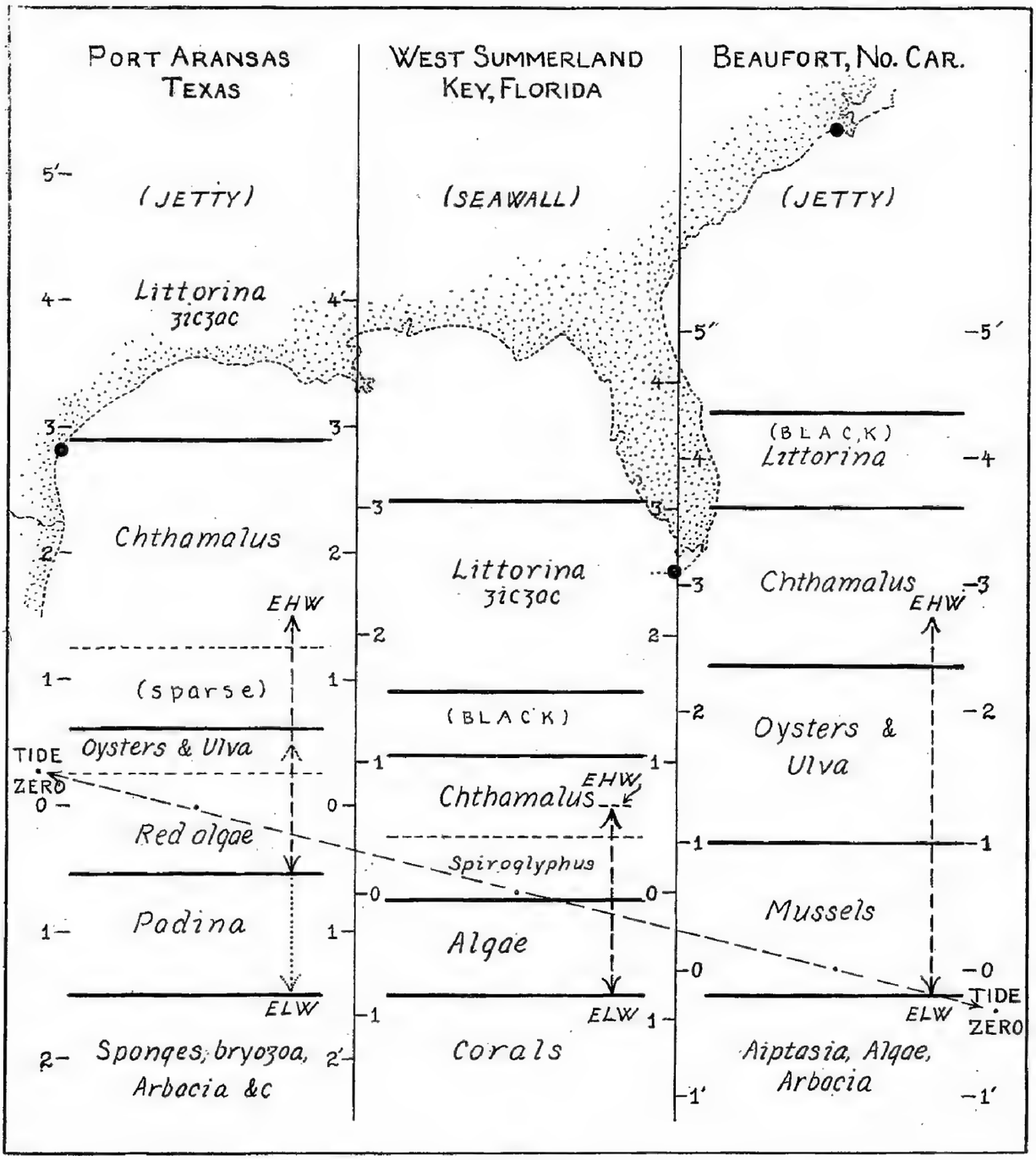

FIGURE 40

Diagram showing comparative patterns of zonation at Port Aransas, Texas, West Summerland Key, Florida, and Beaufort, North Carolina. The vertical arrows indicate the range of tide. Zonation for Florida and North Carolina adapted from T. A. & A. Stephenson, 1950b, 1950a.

There seems to be a tendency for the occurrence of recognizable sub-zones in regions where the tidal pattern is a mixture of diurnal and mixed semi-daily tides, as at Port Aransas and the Florida Keys, as compared with the simpler zonal pattern in an area subject to a regular semi-daily pattern such as that at Beaufort (Figure 41).

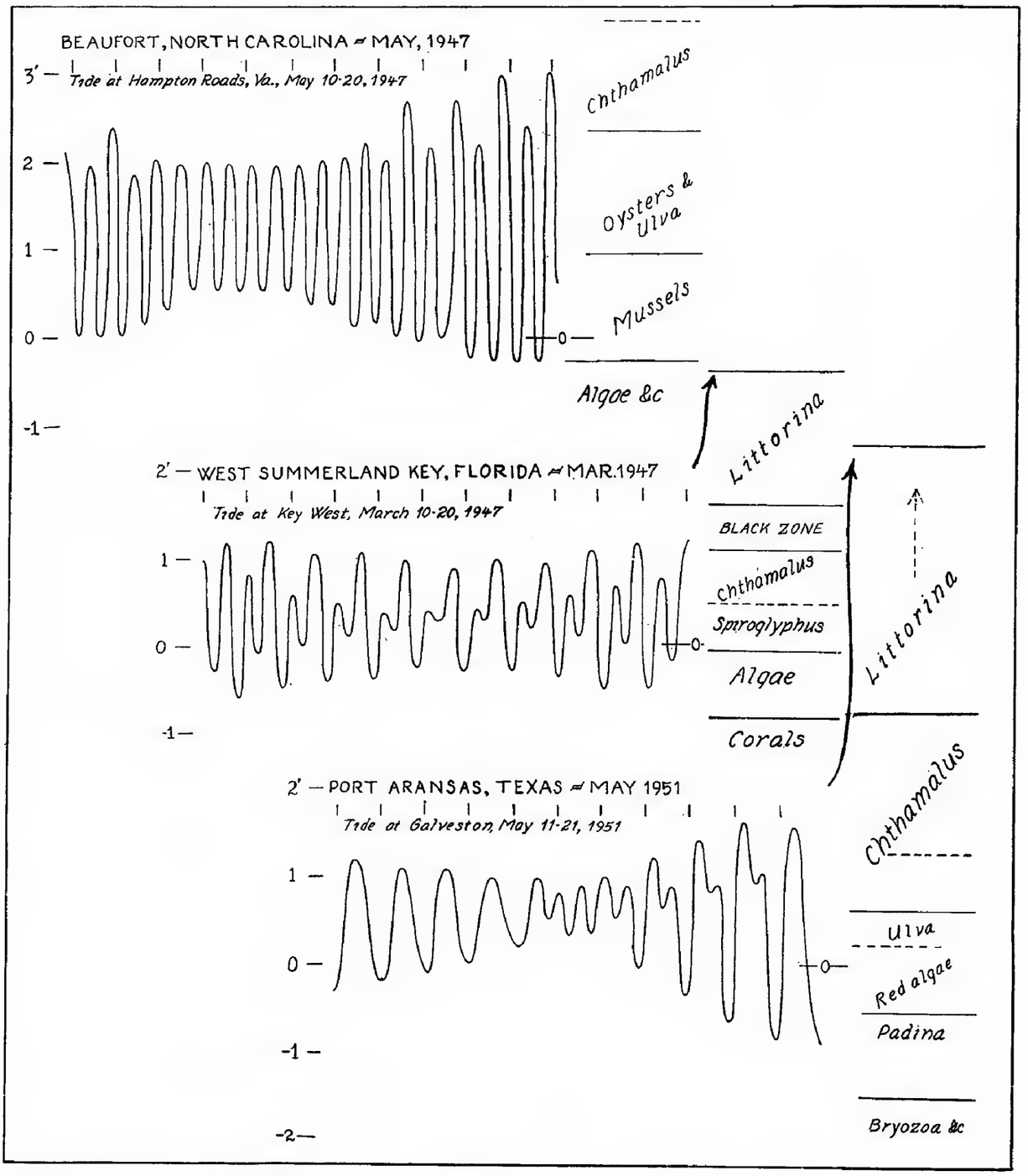

FIGURE 41

Tide curves as related to zonation. The zonation is the same as in Figure 40; the tide curves for the approximate period of three weeks preceding the observed zonation are those predicted for the nearest references points and are not necessarily the same as those at the scene of the field studies, but are probably not greatly different.

A combined scheme of the zonation of both sandy and rocky beaches near Rio de Janeiro is presented by de Oliveira (1948). He recognizes three zones: a barnacle zone, a mussel zone, and an algal zone. The middle zone is divided into a narrow

"green" oyster belt and a broad "brown" mussel belt. This scheme seems to resemble the zonation at Beaufort more closely than that at Port Aransas, although the faunal pattern as a whole is the southern hemisphere counterpart of the mixed type, suggesting again a correlation between sub-zones and irregular tidal cycles.

It is of particular interest to note the manner in which these zones correspond with certain tidal levels, since a direct causal relationship is denied by the Stephensons (1949): "A mistaken idea, which is commonly held, is that intertidal zonation is a result of tidal action. This is not so. Zonation occurs, both above and below water level, round static waters such as ponds and lakes, where there is no tidal change." A more conventional view is that of Feldmann (1951): "On parts of the shore alternately left uncovered at low tide and then reflooded at high tide the algae undergo alternate emersion and submersion, the biological influence of which is manifested by the 'zonation' of species living in this zone of ocillating tides (intertidal belt). . . . Various factors (orientation and inclination of the coast, turbulence of the water, persistence of a more or less high humidity with respect to the nature of the substratum, and the fixed flora and fauna) lead to a disproving of the parallelism which was formerly believed could be established between the tidal levels and the bionomic levels." (p. 317).

This seems to say that the cause is once removed: the Stephensons say the primary cause is the interface between air and water, which in combination with various light and moisture gradients, produces zonation. Nevertheless, the correspondence between zones and tidal levels is a coincidence difficult to dismiss with a brusque statement. On vertical walls and jetty rocks, at any rate, there is an apparent correlation between tide curves and the zones. This was demonstrated many years ago by Johnson and York (1915), who stated that "the vertical range of a littoral plant is exactly proportional to the range of the tide." Doty (1946) has advanced the hypothesis that zonation can be correlated with critical factors of time of exposure or submersion in relation to the different gradients of the tidal cycle.

Intertidal zonation and its possible causes have been the concern of students of the flora and fauna of rocky shores almost exclusively. A thorough understanding of this problem may not be achieved until all aspects of zonation, on all sorts of substrate, are examined in detail. A peculiar aspect of the literature on intertidal zonation is the usual absence of illustrations of the tide curves in connection with the zones, and it is not certain that the authors of some of the published work on zonation have a clear idea of the characteristics of the tides occurring in the vicinity of their studies.

IV

Biogeographical and Ecological Considerations

1. General Relationships

Biogeography, the branch of biology devoted to summarizing and analyzing the distribution of organisms, has two somewhat divergent phases or aspects. The classical or traditional biogeography is concerned with the distribution patterns of faunas, larger systematic categories or related organisms as related to the physical factors on the globe. Insofar as the seas are concerned, the culminating work from this viewpoint is Ekman's Tiergeographie des Meeres (1935) now revised as Zoogeography of

the Sea (1953). An earlier landmark is Ortmann's extended essay (1896), which also provides a good historical summary of marine zoogeography up to that date.[15]

The other approach to the subject is through the ecological relationships of the organisms, initiated long ago by Semper (1881) and most recently summarized by Hesse, Allee and Schmidt (1951), although neither of these works is concerned with

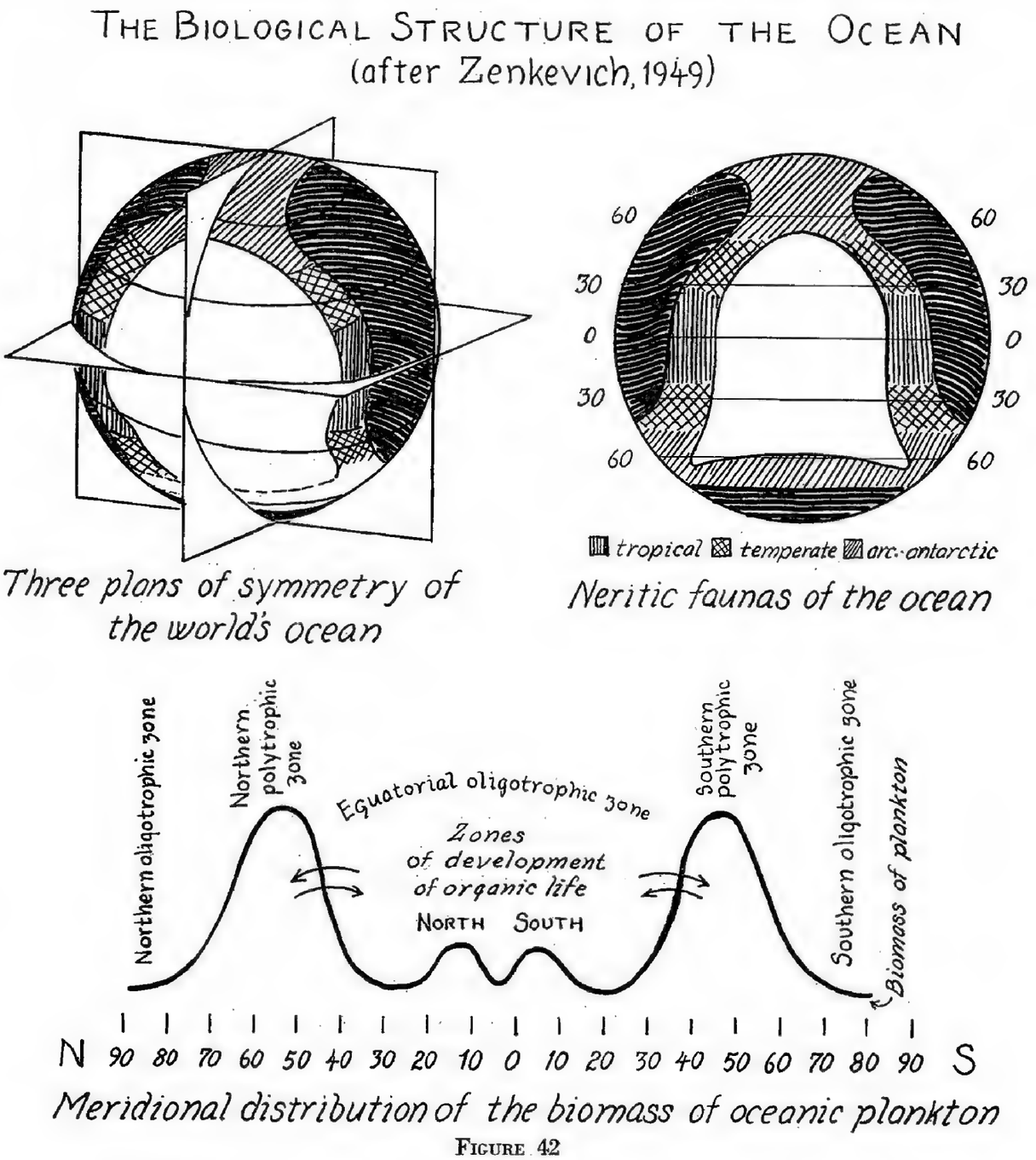

FIGURE 42

The biological structure of the world ocean, according to Zenkevitch (1949).

the seas exclusively. The objectives and methods of marine biogeography were discussed by Zenkevich (1947a), who considers the goal to be a common synthesis of statistical, ecological and historical biogeography, resulting in schemes of "spatial

[15] Several interesting papers on problems of biogeography appeared in vol. 26 of the *Zoologicheski Zhurnal* (1947); Birstein on relics and Nikolsky on faunistic complexes in addition to the paper by Zenkevich. Nikolsky is of the opinion that the classical approach of biogeography "belongs chiefly to the past." The treatment of biogeography as a general synthesis is discussed by Dansereau (1951); his approach is substantially the same as followed in this paper.

typisation of the World's Ocean." The principal unit of this biogeography is the "biomic complex." In a recent paper Zenkevich (1949) drew up a model for the biological structure of the ocean which might be considered a starting point for such a synthesis. This is essentially a representation of the horizontal (latitudinal) gradients against the vertical barriers of the continents (Figure 42).

From the viewpoint of classical biogeography the Gulf of Mexico, like any transitional area, offers difficulties for neat generalizations. The biogeographic status of the fauna of the Gulf of Mexico can be summarized by analysing the distribution of a relatively few organisms. For example three species of littorines occur on the northern Gulf Coast (Figure 43). The temperate species is *Littorina irrorata*, the salt marsh periwinkle, which is found from Massachusetts to the Rio Grande, but skips southern

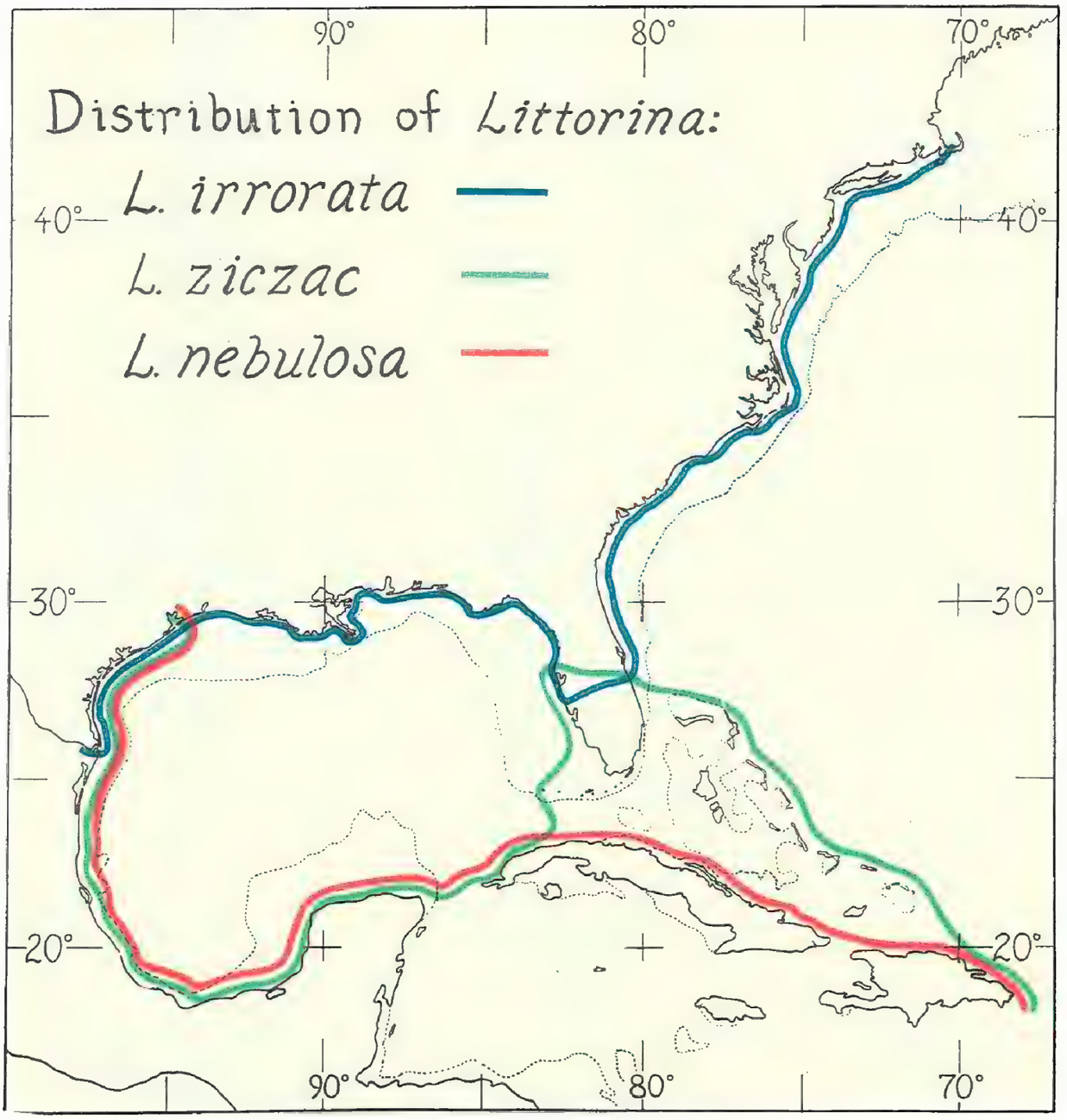

FIGURE 43

The distribution of *Littorina irrorata*, *L. ziczac* and *L. nebulosa* on North American shores. Compiled principally from Bequaert (1943).

Florida. It is an example of the disjunct distribution pattern. A subtropical species is *L. ziczac*, found in southern Florida and on the Texas coast from Galveston southward, but absent from Grand Isle. This species also occurs at Bermuda, and southward through Central America and the Antilles to Brazil. It has also made the journey through the Panama Canal. A third species, *L. nebulosa*, illustrates the sporadic occurrence of a tropical species on the northern Gulf Coast. A few specimens occur on the jetties of south Texas, more rarely on the Galveston jetties, but there is no large, established population of this species on the Texas coast. Thus all three species overlap in the northwestern corner of the Gulf, but nowhere else. Several other tropical species are limited to southern Florida on the North American coast.

Another genus whose distribution illustrates the general character of the Gulf fauna is *Sesarma*, the marsh crab (Figure 44). The two closely related species,

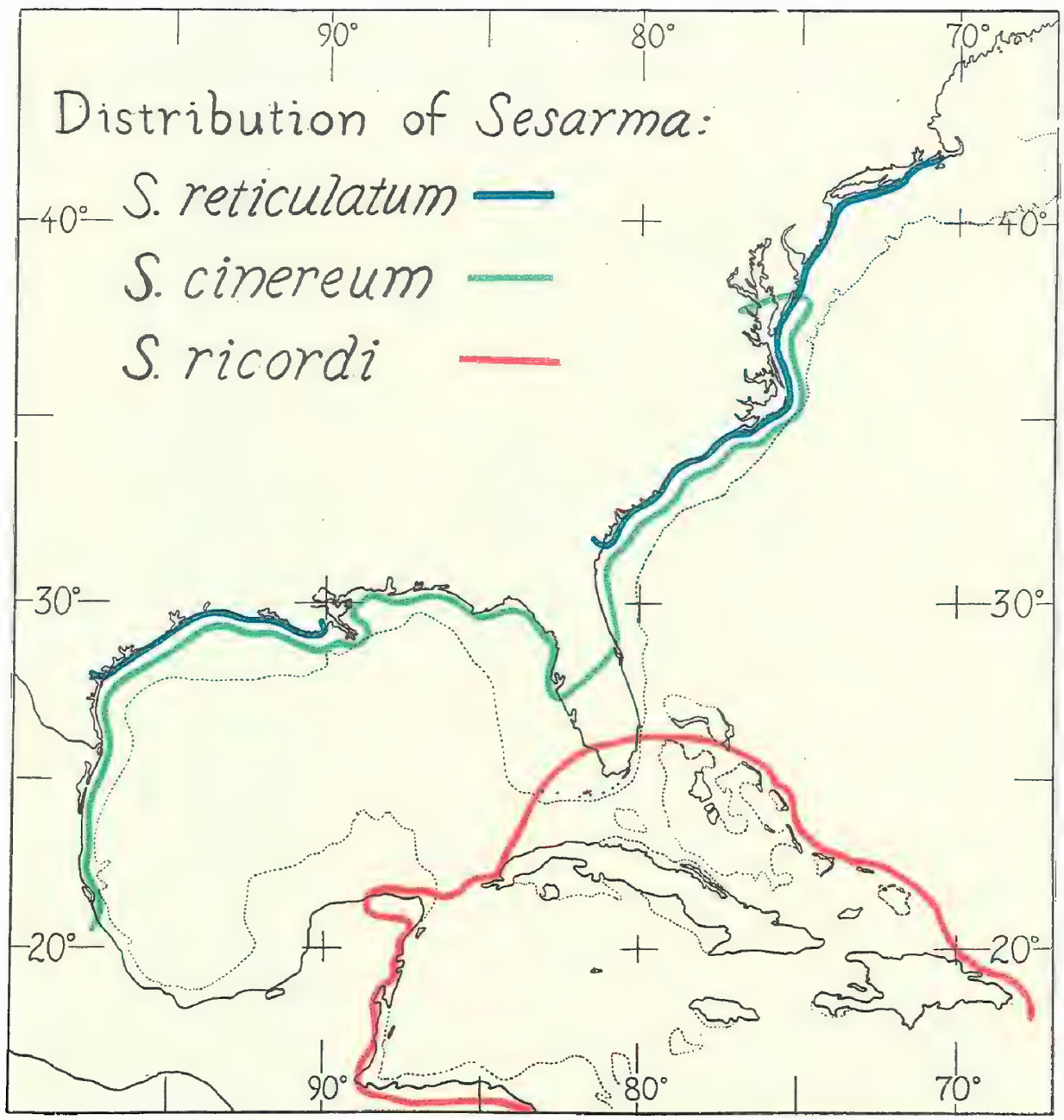

FIGURE 44

The distribution of *Sesarma reticulatum*, *S. cinereum* and *S. ricordi*, modified from Rathbun (1918).

S. reticulatum and *S. cinereum*, have overlapping ranges illustrating the two patterns of temperature distribution on the Atlantic coast, a cold temperate (Virginian) and a warm temperate (Carolinian) species, while the third, *S. ricordi*, is a tropical species whose northern limit is southern Florida. According to Rathbun (1918) this species was collected at Biloxi, Miss., but F. A. Chace informs me *(in litt.)* that these specimens are actually *S. cinereum*.

Not all systematic groups can be neatly arranged in such distribution patterns as *Littorina* and *Sesarma*. The anemones are principally warm temperate species (Carlgren and Hedgpeth, 1952), with a few tropical strays. Taylor (1941) considered the algal flora of Texas predominantly tropical in character. On the other hand, most of the nemerteans known from the northern Gulf Coast belong to the Atlantic coast fauna, or are widespread species found in European or Pacific waters (Coe, 1951). Insofar as their distribution in the Gulf of Mexico is concerned, most of the nemerteans are disjuncts, suggesting a recent separation of this fauna from the Atlantic. The polychaete fauna is even less satisfactory material for generalization. Of 154 species listed from the entire Gulf of Mexico by Hartman (1951), some 23 are endemic (14 newly described). On the basis of this material she divides the polychaete fauna in four principal divisions: an endemic or "delta" fauna, a West Indian element, a circummundane element, and a representation of the Atlantic coast fauna. There is apparently a high percentage of disjuncts in the polychaete fauna of the northern Gulf coast, an indication, possibly, of the still incomplete collecting of polychaetes from southern Florida.[16]

The number of endemic species of polychaetes is higher in proportion than in any of the other larger, well known groups, and the suggestion of a separate "delta fauna" is not supported by the distribution of other groups. The best known (and most numerous) groups are the molluscs and the brachyuran crabs. In the compilation of the mollusca, the pelagic cosmopolitan species and the nudibranchs have been omitted, and a number of species in some genera have been left out because they are inadequately known or appear to be systematic artifacts. Critical examination of the genera *Tellina*, *Donax* and *Terebra*, for example, would doubtless reduce the number of Gulf species assigned to them.[17]

In addition to these taxonomic complications, collections are inadequate. An indication of inadequate collecting in the western Gulf was the recent discovery and description of two apparently common and fairly conspicuous bivalves, *Pitar cordata* and *Anadara baughmani*.[18]

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[16] In some groups the status is even less satisfactory; of the nematodes, Chitwood (1951) writes "at least 50 years will be required before our information is sufficiently stabilized to permit general [geographic distribution] discussions."

[17] In his check list of Texas molluscs Pulley (1952) makes this statement: "No attempt has been made to include synonymies, and many of the species attributed here to other authors bear the names which are now considered correct rather than the names under which they have appeared in lists of Texas shells." As a result of this procedure, several names unfamiliar to bystanders are used, and it is of course not certain whether the more familiar name is considered a synonym or a misidentification. Obviously our crying need is an acceptable reference monograph on western Atlantic molluscs and some way should be found to accelerate the present glacial pace of *Johnsonia*.

[18] These two clams were collected not once, but several times. The description of *Pitar* (as *Pitaria*) *cordata* by Schwengel (Nautilus, **64** (4), pp. 118–119) in April, 1951, left two other descriptions withering on the vine. The race for the honor of describing the *Anadara* was too close for the comfort of the principals, especially in view of certain commercial overtones ("type lot" specimens available for a nominal sum); the race was won by Hertlein for *Anadara baughmani*

Deevey's (1950) analysis of the hydroids from Texas and Louisiana has been mentioned several times in other connections. Hydroids are not very satisfactory material for biogeographic treatment because of the apparently ubiquitous distribution of many species, the unsatisfactory state of hydroid taxonomy and the complex life cycles of the species. Nevertheless, Deevey identified several species whose distribution suggested that they are relicts of a glacial age. His disjuncts, however, are not strictly western Atlantic species, but occur on both sides of the Atlantic or in the Pacific, and the possibility that boreal species have been brought on oil tankers sailing from Wilmington, Delaware, to Port Aransas during the winter months cannot be ignored. Such a journey might have induced the hydroid to reproduce about the time the ship would reach the Texas coast. More implausible cases of distribution have been recorded, *e.g.*, the transfer of organisms like *Rhithropanopeus* and *Molgula* across the continent on oysters to Pacific coast bays, and the occurrence of two warm temperate crustaceans, *Synalpheus fritzmülleri* and *Nerocila acuminata* in Greenland water (Stephensen, 1950).[19]

If the distribution of several groups of animals recorded from Texas and Louisiana is tabulated, several groups, especially molluscs and crabs, show fairly large disjunct elements (Table 7). This table was prepared in the following manner: The

TABLE 7

General distribution of various invertebrate groups occurring between the Mississippi and the Rio Grande

	Appx. No. Species	N to Woods Hole	disj.†	N to Hatteras	disj.†	West Indies	Extra Limit	Endemic Gulf
Hyroids	40	3	----	----	----	7	26(2*)	2
Actiniaria	13	2	----	3	1	3	1*	3
Nemertea	16	5	4	----	----	----	9*	2
Mollusca								
Pelecypoda	101	23	14	38	10	26	----	11
Gastropoda	71	19	9	23	3	16	----	7
Polychaeta	58	12	5	12	9	7	12(2*)	12
Crabs								
Oxystomes	15	2	----	7	----	3	----	3
Spider	11	4	----	4	----	3	----	----
Cancroids	27	6	2	12	----	8	----	1
Grapsoids	20	8	4	5	2	5	----	2
Echinoderms	24	3	2	7	----	10	----	3

* Disjunct on Atlantic coast.
† Number given is from those listed in preceding column.

distribution of western Atlantic and West Indian species as far north as Woods Hole was entered in the first column, those in this category not found in southern Florida and the West Indies were entered again as disjuncts. The same procedure was fol-

in Texas Journal of Science for "September 30, 1951" [**3** (3), pp. 486–489], with Rehder and Abbott a close second with *Anadara springeri* in Revista Malacologia of November 12 [Rev. soc. malacol. Havana, **8** (2), p. 54]. A more detailed account of this indecorous affair will appear in a forthcoming issue of Systematic Zoology.

[19] Such erratic distributions are not uncommon, and should be borne in mind by paleontologists. In view of records like this and the ranges of many western Atlantic species from New England to Brazil, the exchange of views by Richardson (1948) and Newell (1949), concerned principally with problems of systematics (*i.e.*, concern over the validity of the determination of a wide-ranging trilobite) seems somewhat beside the point. For a list of emigrants to the Pacific Coast, see my "Newcomers to the Pacific Coast" in Ricketts and Calvin Between Pacific Tides, pp. 399–401, 3rd ed. Stanford Univ. Press, 1952).

lowed for those ranging as far north as Hatteras, or, in a few cases, to Chesapeake Bay. In the West Indies column are included the species ranging to Texas and South Florida (many of the non-disjunct Woods Hole and Hatteras species are actually cold-tolerant West Indian species). Species—or varieties—known only from the Gulf of Mexico were considered endemic, although some of these are known only from the original collection. In the "extra-limital" column are included the widespread species whose occurrence in western Atlantic waters use only part of their range. Often they occur as disjuncts in this region, like Deevey's hydroids. It should be realized that while this tabulation may err in detail, it probably represents the approximate situation; it is, so to speak, in the "right order of magnitude."

Among other things, this table shows that hydroids are the least satisfactory of the various groups listed for the purpose, and that the percentage of endemism is usually around 10. Phleger and Parker (1951) found 15% endemism in the foraminifera, but this estimate may include some now extinct species. According to Woodward's classical definition of a province as a region where 50% of the species are endemic, the northern Gulf of Mexico is not even a good province.

While this analysis is based on the invertebrate fauna, similar data could be obtained from the fish fauna, as Gunter has pointed out: "Along the South Atlantic and Gulf coasts of the United States the fish fauna is similar, but along both coasts of Florida there is a break or transition where the fauna turns tropical and West Indian. This problem has never been studied specifically, but the correctness of the statement is shown by general observation." (Gunter *et al.*, 1948).

Temperature, and perhaps salinity, may be the principal factors controlling the disjunct distribution of many forms, but ecological factors should not be overlooked. Concerning the distribution of the three closely related species of grooved shrimp in western Atlantic waters, Burkenroad (1939) suggests that the absence of *Penaeus duorarum* from Brazil and *P. brasiliensis* from the northern Gulf of Mexico, and the abundance of *P. aztecus* in the latter region may be a result of interspecific competition, with differential salinity preferences at various juvenile stages the immediate selective influence. Since there are many such closely related groups of species in the western Atlantic, this hypothesis deserves more consideration.

The biogeographic status of the Gulf of Mexico might well be summarized on the basis of the echinoderm fauna, since these animals are stenohaline and usually stenothermal. Of the 24 species known to occur on the coasts of Texas and Louisiana, ten are West Indian forms, and seven range only as far northward as Hatteras. Three species range northward to New England, two of them, *Arbacia punctulata* and *Thyone briareus*, as disjuncts, and three are endemic *(Molpadia cubana, Thyone mexicana* and *Paracaudina obesacauda)*. In addition to these, there are several other species in the northeastern Gulf, one of which *(Asteroporpa lindneri)* is the only Atlantic representative of an Indo-Pacific genus (Clark, 1948). *Paracaudina obesacauda* was formerly considered to be a variety of a Pacific species, but has been elevated to specific rank. Nevertheless the species indicates the close relationship between Caribbean and Pacific faunas; Ekman (1946) has emphasized this relationship, pointing out that the Pacific Ocean has been an effective barrier to dispersal since the rising of the Isthmus in Tertiary times. An example of a transoceanic stray in the Atlantic is the Mediterranean Eastern Atlantic *Thyone inermis*, collected

occasionally near Cuba as juveniles, but never as adults. Deichmann (1947) suggested that the larvae drift across from the Azores, but that the animal apparently cannot mature in Caribbean waters.

2. Provinces and Zones

Probably more ink has been expended on the discussion and delineation of provinces than upon any other topic in marine biogeography. For the most part this has been done by students of particular groups, especially by the conchologists. In the past this has been empirical, and the faunistic divisions—or their limits—proposed have varied with the judgment of the author. This situation is similar to that encountered in physiography (now geomorphology): "The only reason for using one set of divisions rather than another, or for adhering to one scheme for general use, is that it most often fits the needs of the discussion. This is about equivalent to saying that the best scheme of divisions into provinces is the one which makes possible the largest number of generalizations about each." (Fennemann, 1938, p. vi).

The status of molluscan provinces along the Atlantic coast of North America is summarized by Johnson (1934). There has been little change in the delineation of Atlantic molluscan provinces since Fischer's (1887) days. The Arctic Province extends southward to Newfoundland, roughly the southern limit of floating ice. The Boreal Province, roughly from Nova Scotia to Cape Cod, is perhaps more in the nature of a broad overlap rather than a distinct province. The Atlantic coast from Cape Cod to Cape Canaveral constitutes the Transatlantic Province, which some authors divided into Virginian, Cape Cod to Hatteras, and Carolinian, Hatteras to Florida. These subdivisions are essentially the southern overlap of the northern fauna and the northern overlap of the southern fauna. Pearse and Williams (1951) in their description of the fauna of serpuloid and vermetid reefs off the Carolina coast list 167 species as southern in relationship, 18 as northern species ranging south, and 63 as "eurythermal." Ortman (1896) considered Hatteras the primary division point on the Atlantic coast.

While stating that "almost any area between the arctic and the tropics is more or less transitional," Johnson offers this summary of the Transatlantic Province: "The Transatlantic Province can be characterized by that typical American genus *Busycon*, the region in which the oyster can be successfully propagated, and in which the hard shell clam, *Venus mercenaria*, abounds."

The next province is the Caribbean, whose northern limit is southern Florida, perhaps as far as Cape Canaveral on the east coast and on the west coast certainly as far north as Sanibel Island or Tampa. The old conchologists, *e.g.*, Fischer, included the entire Gulf of Mexico in this essentially tropical province, an interpretation which has been modified by subsequent data: "Along the northern shore, however, from Cedar Keys to Texas, there is a strong influx of the transatlantic species, which probably reached that section before the peninsula of Florida was formed. Five species of *Busycon* are recorded from the Gulf, one *Busycon coarctatum* Sby. is probably extinct [this species has recently been collected in numbers on the Campeche banks. J. W. H.], while *B. carica* and *B. canaliculatum* are confined to the northern part. There are also present in the Caribbean Province many Mediter-

ranean and Pacific species, the latter reaching this section in the late Eocene or early Oligocene when the Atlantic and Pacific were connected at the Isthmus of Panama" (Johnson, p. 9).

In the distribution list of southeastern Atlantic Mollusca compiled by Dall (1889), the region is divided into 10 districts. "Texas" in this list comprises the coast line from the Mississippi Delta to Yucatan, and southern Florida is delimited as that part south of Biscayne Bay on the east and of Charlotte Harbor on the west. The west Florida division of Dall's table comprises the coast from Charlotte Harbor to the Delta. As far as the shore and bay faunas are concerned, there is no well-defined faunal break at the Delta. Some species are absent from near the Delta, either because of low salinities or the high sediment content of the water, but many species occur along the northern Gulf Coast from Cedar Keys to Corpus Christi. These are, on the whole, the animals which comprise the characteristic facies of this coast: the ark shells, mussels and oysters among the bivalves. *Busycon, Polinices* and *Odostomia* among the gastropods, and such characteristic crustaceans as the blue crab, various mud crabs and the penaeid shrimp. There are several distribution anomalies, such as the occurrence of *Limulus* no further west than the Chandeleurs (except for one isolated record from near Port Aransas), the localized population of *Eurytium limosum* (a xanthid crab) in the Grand Isle area and the occurrence of the crown shell *Melongena corona* at Pensacola but not in Texas, and the apparent absence of *Pinnotheres ostreum* from the northeast Gulf of Mexico although it is common in oysters at Cedar Bayou. The differences are those of local distributions, and it cannot be said that there are two well-defined biogeographic divisions along the northern Gulf coast. Ginsburg (1952), points out a similar distribution for fishes, with an apparent break between Alabama and west Florida. He does not consider the Delta a major faunal barrier.

On the basis of a study of the distribution of bivalves and the mean shore temperature data of the Coast & Geodetic Survey Pulley (1953) has proposed 11 provinces from Nova Scotia to the West Indies. Four of these provinces, which are considered to be "regions of faunal uniformity, bounded on either side by regions of faunal transition," lie in the northern Gulf of Mexico. It is not plain, at least from Pulley's abstract, whether the regions of transition are also considered to be provinces, since his proposed names for the Gulf suggest both zones of uniformity and transition and no overlaps are indicated. On the Atlantic coast he recognizes the traditional Boreal (as Nova Scotian), Virginian and Carolinian provinces, and divides the Atlantic and Gulf coasts of southern Florida into seperate provinces. For the northern Gulf coast, Pulley proposes the following provinces:

Northeast Gulf	Anclote Keys to Mississippi River
Northwest Gulf	Mississippi River to Matagorda Island
Texas Transitional	Matagorda Island to Cabo Rojo (S. of Tampico)
Offshore West Indian	25–100 fathoms in the Caribbean Sea and Gulf of Mexico.

This system suggests that the essential faunal continuity between the northern Gulf and the southeast Atlantic coasts is minimized in favor of emphasizing a particulate concept of provinces and that the separation or break at Matagorda Island may be an artifact of the collections available to Pulley. Obviously much more collecting and detailed analyses are needed to clarify the questions raised by these studies. Insofar as the invertebrates in general are concerned, the northeast corner of the Gulf seems

to have a few more tropical strays than the northwestern part of the Gulf, but more collecting has been done east of the Delta.

Schenck and Keen (1936, 1940) proposed a statistical method of defining provinces. This involves, in effect, "the three most important qualities of a straight line: the location of the center, the length, and the location of the ends." These are the midpoints of range, the total distribution, and the end points of range. By tabulating these aspects of distribution without regard to population densities or bathymetric range, and plotting them, a series of curves is derived. The peaks are presumed to indicate the center of the province, the lows the "overlap" areas. From this study Schenck and Keen propose to define a province as follows: "A marine molluscan province is a subdivision of a region, subregion, or realm, populated by a distinctive assemblage of species. Distinctiveness is not simply a matter of ecologic situation but of spacial [*sic*] extent or range. A province has at its center a high percentage of species with restricted ranges; the periphery, on the contrary, is marked by species of wide distribution. The size of the province being variable, its limits are best defined by statistical methods." (1936, p. 923.)

While their method has been applied in detail only to the Pacific coast of North America, they suggest its applicability to the Atlantic coast (1940) on the basis of Johnson's check list. Aside from the dubious value of the latitudinal midpoint of a known range, which, as Newell (1948) says, is "utterly devoid of any intrinsic biological significance," the peculiarities of distribution on the Atlantic coast do not justify such faith in Johnson's list however well established the *limits* of distribution may be. There are far too many ranges cited as "Massachusetts to Texas" without adequate indication of the status of the species in southern Florida. For example, the range of *Arca transversa* is given as "Massachusetts to Texas." Examination of the collections of the U. S. National Museum reveals that both Massachusetts and south Florida are represented by small lots of stunted individuals, and that the range should be extended at least as far south as Vera Cruz. It would seem, at least from these collections, that neither Woods Hole nor south Florida offer optimum conditions for this species, and that we are here dealing with a warm temperate species limited at the northern part of its range by temperature, and in southern Florida by some other factor, possibly coral sands. Thus the "mid-point" of its range may fall in a region where the species is uncommon or its representation is not typical of the species as a whole. Other species may be absent from south Florida because suitable estuarine conditions are lacking. This may be the case for *Polymesoda caroliniana*, which van der Schalie (1933) plots on a typical disjunct pattern. Similar qualifications are necessary for many other species, and, together with the fantastic nomenclatural jumble which clouds the title to many of the most common molluscan names, render the use of Johnson's check list for such purposes a risky business. Furthermore, the geographical peculiarities of the Atlantic coast are not amendable to the sort of treatment applied to the more regular Pacific coast.

As desirable as it may be to establish a non-subjective basis for assessing distribution patterns, it does not seem that the scheme proposed by Schenck and Keen is adequate. It errs on the side of abstract objectivity by not taking population densities and breeding periods into consideration and in emphasizing extremes. As Ricketts *(in* Steinbeck and Ricketts, 1941) has pointed out, "the animals important in marine

sociology are not museum rarities, but the common and obvious forms which make up the bulk of the population."

A more logical step is the zonal typology scheme of Hutchins (1947), based on the critical limits for survival and reproduction, in terms of summer and winter temperatures. Four types of distribution patterns are recognized, of which two are applicable to the northern Gulf of Mexico (Figure 45). These are the zones defined by temperatures governing repopulation both north and south (Type 2) and the other by the winter survival temperatures and summer repopulation temperatures (Type 4). In the first type of zonation we find animals which spawn in late spring and summer in the northern part of their range, and in late winter in Texas and Florida. *Arbacia punctu-*

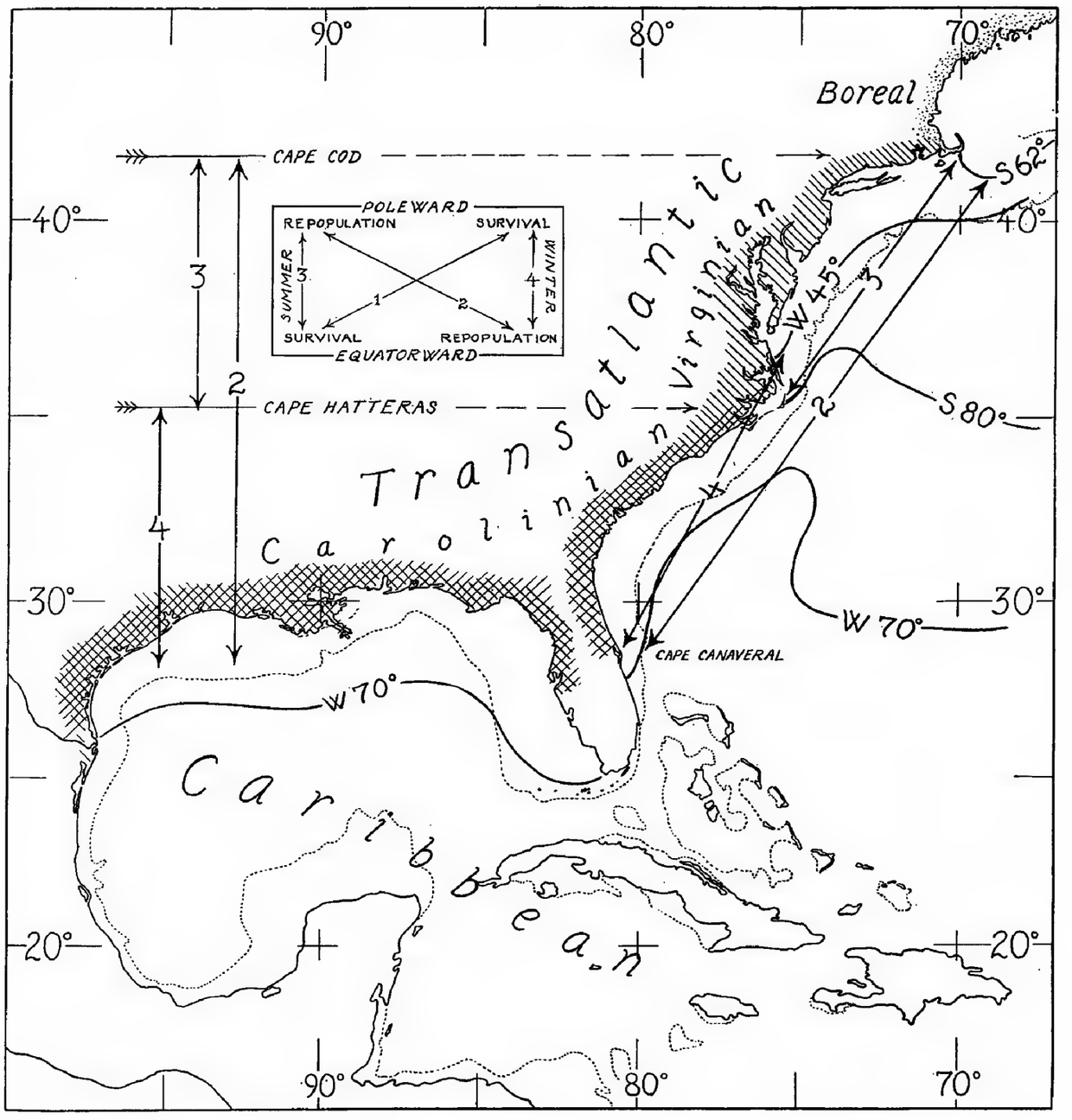

FIGURE 45

Map showing the extent of traditional provinces on the Atlantic and Gulf coasts, together with Hutchins's scheme of zonal typology and the isotherms governing the limits of zones 2, 3, and 4.

lata is one of the best examples of this; it spawns at Woods Hole during the summer and Port Aransas in February and March. Another example of this is the crab *Rhithropanopeus harrisi,* which spawns in New Brunswick in August (Connolly, 1925) and in Texas in May.

In the other type of zonation are to be found most of the warm temperate animals which spawn during spring on the Gulf coast, and are sluggish during severe cold spells if they remain in the bays (e.g. *Callinectes sapidus*).

According to Hutchins' scheme, certain organisms, falling into his type 1, should not occur on the Atlantic coast at all. The example he gives of such distribution as the hydroid *Syncoryne eximia,* which Deevey recognizes from the Gulf Coast, and from the Atlantic coast at Beaufort and various Florida localities north of Cape Canaveral. This, according to Deevey, thoroughly spoils the scheme, but a single species is a weak reed for either defense or prosecution to hang their cases on, and the possibility that a closely related southern species of *Syncoryne* may have been confused with the northern one cannot be overlooked. The Port Aransas identification is based on fragmentary material. Type 3 zonation should also be absent from the Gulf Coast, and the species selected by Hutchins as typical of this type, *Mytilus edulis,* occurs only north of Beaufort.

It does not follow, of course, that all organisms whose distributions follow the pattern of zones 2 and 4 occur in the Gulf of Mexico. *Balanus balanoides,* characteristic of zone 2, has not been authentically reported from the northern Gulf Coast; the record for Grand Isle given by Behre (1950) is dubious.

While Hutchins' scheme offers much promise as a means of summarizing the distribution of species, it does not provide us with a means of classifying communities or comparing areas on different coasts, nor can it serve very well as a basis for determining the "biomic complex" which Zenkevich (1947a) considers the principal biogeographic unit. It is not a primary scheme of classification, but an additional tool for biogeographic analysis. With this scheme must be combined the quantitative analysis of the communities. This has been tried in two ways: the analysis of populations by species in natural areas, as originated by C. J. G. Petersen (see Jones, 1950, for references), and by statistically determined ecological areas arrived at by plotting population densities on a temperature-depth grid system (Zenkewitch and Brotzky, 1939; Brotskaya and Zenkevich, 1939). Since quantitative bottom community investigations are yet to be made in Gulf of Mexico and western Atlantic waters, this synthesis cannot be attempted at this time.

3. **Community Relationships**

The classification of communities on ecological principles is, unfortunately, complicated by a maze of terminology. This terminology varies in meaning with the author, so that comparable situations may bear different labels, or the same term may mean one thing in ecology and another in biogeography. This is tacitly admitted by Hesse, Allee and Schmidt (1951, p. 168) in their discussion of the limits of niches and biocoenoses. The primary topographic unit, according to the system of these authors, is the niche or biotope (to be distinguished from the "habitat niches" of ecology). A sand beach, for example, is a biotope. This is a division of a biochore (the seacoast), the subbiochore depositing shore. The biochore seacoast is in turn

a division of the superbiochore benthal, a part of the biocycle ocean. This does not seem to be an improvement over the simple designation "sand beach."

A biotope is occupied by a biocoenosis (*cf.* Caspers, 1950a), or interrelated community, which may have facies (variations or faciations) and which are not necessarily coextensive with the biotope. The sand beach of the Bulgarian coast has been termed the "*Orchestia* variation" of the "*Pachygrapsus* biocoensis" (Caspers, 1951a); on comparable grounds the sand beach of Texas could be called the *Orchestia* biocoenosis, and the jetties the *Pachygrapsus* variation thereof. The beach might as easily be called the *Ocypode* biocoenosis or the *Donax* biocoenosis according to Caspers' standards. This terminology tells us little about the actual conditions, such as temperature and salinity, which are found in these two physically similar environments, nor that the *Pachygrapsus* variation on jetties in Texas is a result of colonization. About all this adds up to is that similar groupings of organisms are found in similar places, without conveying any idea of the possibly different processes by which the similarities have been attained.

Estuarine faunas, in particular, resemble each other in various parts of the world, although the estuaries themselves may have little in common but similar ranges of variability in their factors. Certain estuarine species are almost world-wide in their distribution. One of the most noteworthy of these is an anemone, *Aiptasiomorpha luciae*, found in Japan, California, on both sides of the Atlantic, in the Mediterranean at Naples and in the Adriatic. It occurs sporadically at Port Aransas. Uchida (1932) suggested that the species is Japanese in origin and that it has spread from there in the last 100 years. Whether its arrival on the Gulf Coast is a recent event or an older colonization cannot be said. Several Atlantic coast estuarine animals have managed to cross the ocean to Europe. *Crepidula fornicata* is one of the best known of these (Orton, 1950; Spärck, 1950); this species has also turned up on the Pacific coast although it does not seem to be established. Another eastern species, *Crepidula glauca (= convexa)* is naturalized in San Francisco Bay (Coe, 1949). The small brackish water crab *Rhithropanopeus harrisi* had been known in the Zuider Zee for many years, and more recently in the estuaries of the Bug and the Dnieper, although under the name *Heteropanope tridentata* (Buitendijk and Holthuis, 1949). These authors also remark on the occurrence of the Atlantic American medusa, *Nemopsis bachei*, in the Zuider Zee; this is the common small medusa of Texas bays.[20]

These examples of dispersal indicate not only the extraordinary capacity of estuarine animals to accomplish migrations, but the similarity of the environment. Indeed, estuaries may be characterized by their fauna: a region populated by *Palaemonetes*, cyprinodont fishes, small xanthid crabs, oysters and mussels, can be nothing else but an estuary, although the physical characteristics of no two estuaries can be compared in all details. Thus an estuary is a biotope, but one not necessarily occupied by a biocoenosis. An aggregation of organisms whose occurrence together in a given biotope seems to be more a coincidence of overlapping ranges than of interdependency, is simply a "community." The term is also the

[20] Occasionally *Callinectes sapidus* turns up on European shores; Hartog and Holthuis (1951) have listed a number of records for this species from the Dutch coast.

general utility category of ecology. (See Gislén, 1944, and Jones, 1950, for a discussion of the community concept in marine ecology.)

Probably one of the most famous marine communities, if not a true biocoenosis in the sense of complete interdependency, is the sargassum community. Here the biotope is the organic substratum provided by the gulfweed, but since many of the members of the community are plankton feeders, depending upon allocthonous sources, the interrelationships are not as complete as the specific relation to the substrate would suggest. While the biota of this alga in both the Atlantic and the Gulf of Mexico has many species in common, including the sargassum fish *Histrio histrio*, the nudibranch *Scyllaea pelagica*, the small snail *Litiopa melanostoma*, the polychaete *Platynereis dumerili* and a host of hydroids (these differ according to the type of sargassum, however—Burkenroad, *in* Parr, 1939), there seem to be differences in this fauna in the two regions. One conspicuous difference, at least so far as known, is the absence of *Planes minutus*. There are also differences between the sargassum fauna of uprooted shore weed and that of holopelagic sargassum. Some of the weed drifting ashore on the Texas coast belongs to the former category, as indicated by the occurrence of the pycnogonid *Tanystylum intermedium* and the absence of Columbus' crab, *Planes minutus* (Chase, 1951). The conspicuous green pycnogonid, *Endeis spinosa*, has not been found on stranded gulfweed on the Texas coast, but there is some question as to whether this is a species of eupelagic sargassum or whether it is a hitch-hiker on the weed. Both *Planes* and *Endeis* are reported from sargassum at Tortugas. The illustration of the fauna of a sargassum bladder (Figure 46) suggests, with such things as juvenile ophiurans, and *Tanystylum* a fauna characteristic of uprooted rather than high seas or holopelagic weed.

The problem of the *Sargassum* and its fauna has attracted the attention of many naturalists, but the literature is badly scattered. There is need for a thorough canvass of the literature, with a critical list of the species represented in the fauna.

While the concepts of biotope, biocoenosis and community seem clear enough, the terminology of higher categories is vague, and recent literature has done little to clarify matters in spite of Tansley's (1935) noble effort. Jones (1950) accepted the notion of Clements and Shelford (1939) that marine bottom aggregations are climax communities and therefore should be termed "biomes," and proceeds to set up a classification of communities in the north Atlantic based upon the physical characteristics of the environment. Under "Shallow water and brackish communities" for example, he includes a "shallow soft bottom biome" subdivided into "shallow sand association" and "shallow mud association" and a "shallow hard bottom biome," with a "shallow rock association" and a "shallow vegetation association," and so on. These "biomes" are actually biotopes. The biome of terrestrial ecology is, in its simplest meaning, the end-point of the prevailing environmental conditions, *i.e.*, the climax formation of a major climatic region, and is according to this conception a relatively stable phenomenon subject to change when the climate changes. The only biotic phenomenon in the sea which seems to satisfy this concept is the tropical reef formation.

The rocky intertidal region is considered to resemble a terrestrial climatic complex, or biome, by Beveridge and Chapman (1950), while Marshall (1953) proposes the term "Balanoid Biome-Type" for that part of the shore in which barnacles are "domi-

nant." But the intertidal region is occupied by a fringe community, both literally and ecologically. And like a fringe, it has been ornately subdivided by terminology. The meanings and limits of these terms vary with the investigator and the shore investigated; for details concerning this battle of terminology, see the papers by Stephenson and Stephenson (1949), Womersley and Edmonds (1952) and Chapman and Trevarthen (1953).

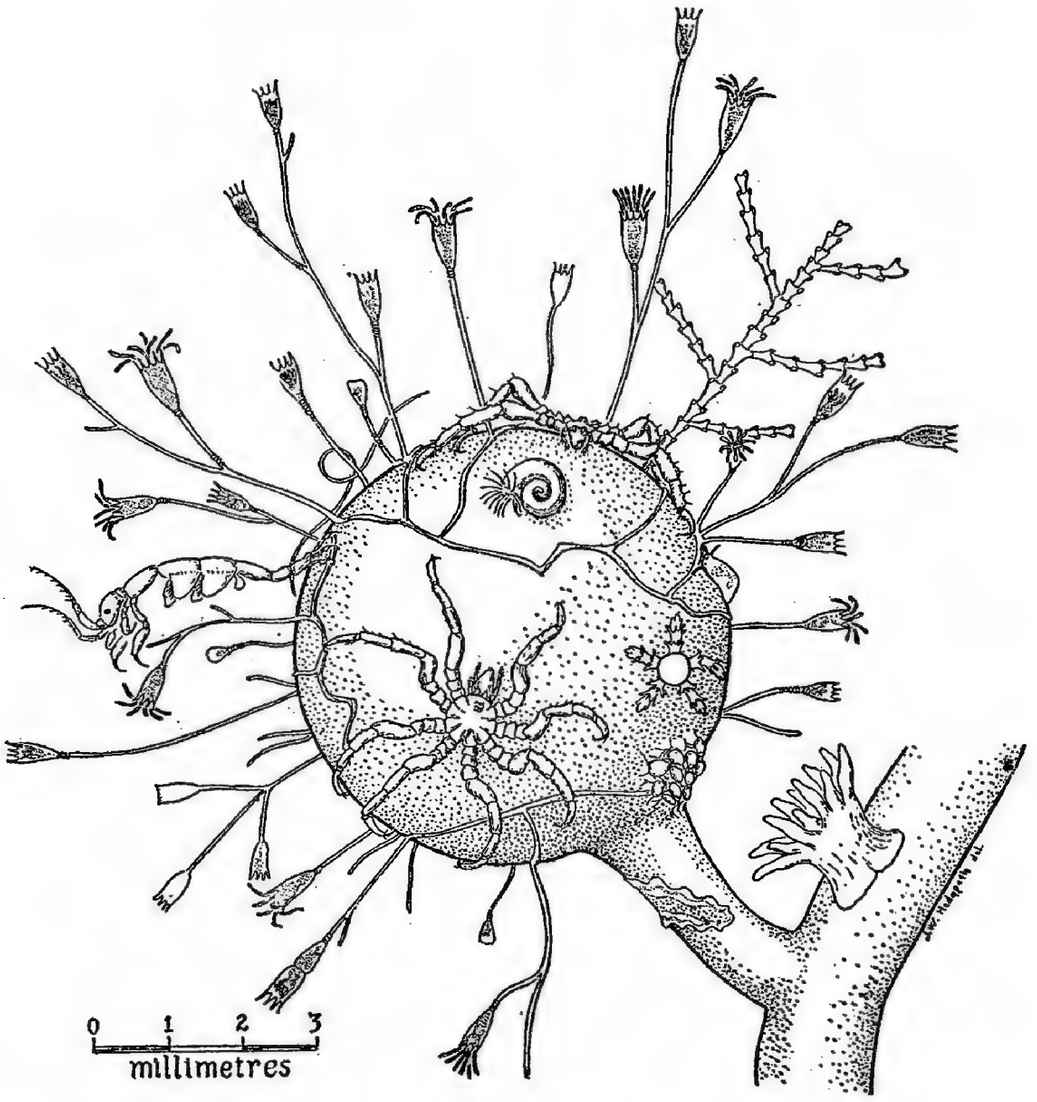

FIGURE 46

The faunal association of a sargassum bladder, Texas coast. The hydroids are *Obelia* and *Sertularia*, the pycnogonid is *Tanystylum orbiculare*. Other forms include the sargassum anemone, *Anemonia sargassensis*, a caprellid, a flatworm, a small tubiculous polychaetes *(Spirorbis)*, a juvenile ophiuran and a small colony of bryozoa. (From Hedgpeth, 1948.)

Conditions in the sea are best described in the terms which Tansley (1935, pp. 229–300) used in discussing his concept of the ecosystem:

. . . the more fundamental conception is, as it seems to me, the whole *system* (in the sense of physics), including not only the organism complex, but also the whole complex of physical factors in the widest sense. . . . It is the systems so formed which, from the point of view of the ecologist, are the basic units of nature on the face of the earth. . . . These *ecosystems*, as we may call them, are of the most various kinds and sizes. They form one category of the multitudinous physical

systems of the universe, which range from the universe as a whole down to the atom. . . . Some of the systems are more isolated in nature, more autonomous, than others. They all show organization, which is the inevitable result of the interactions and consequent adjustment of their components. If organization of the possible elements of a system does not result, no system forms or an incipient system breaks up. There is in fact a kind of natural selection of incipient systems, and those which can attain the most stable equilibrium survive the longest. It is in this way that the dynamic equilibrium . . . is attained.

Thus an ecosystem may be regarded as any portion of space, with its endurance in time, which contains living matter, and is always organized in the sense that interadjustments of its components, living and nonliving, is in continuous process.[21] The great advantage of this concept for the marine ecologist is that it requires attention to be focused, not on terminological descriptions of the *status quo* but on the dynamic relationships which are nakedly preëminent in the sea. The importance of time in ecology cannot—and probably never has been—denied, but it too often does not receive its due emphasis, and certainly it is in the sea that time cannot be ignored as the essential component in the organization of communities: "Nothing . . . that but doth suffer a sea change. . . ." (Shakespeare, 1611).

In the northern Gulf of Mexico we find an ecological complex which requires both estuarine and neritic waters for its full development. For the purposes of analytical discussion this whole region from inner bay shores to perhaps 15–20 fathoms (or some possible shear zone between neritic and oceanic conditions) is occupied by what should be regarded as a single major ecosystem, which is similar to that on the Atlantic coast, or the near shore waters of South Asia. The larger living components of this ecosystem, characteristic of the transitional waters between the tropics and the temperate zone, consist primarily of penaeid shrimp and various other decapod crustacea, sciaenid fish (croakers), the worms which comprise the next trophic level of the Eltonian pyramid below these organisms, a secondary estuarine system including the oyster biocoenesis, and various minor communities. Corresponding ecosystems are those including the tropical reefs and lagoons (where the physical factors of wave action and basaltic substrate are integral components), the herring-bottom fish complex of neritic temperate and boreal seas, with its varied array of infaunas, and the blue whale-euphausiid complex of the Antarctic. Perhaps the largest—and the most truly marine—ecosystem is that of the bathypelagic region, including the complex of small black fishes, brilliant red shrimp (principally carideans) and a host of other creatures. Practically nothing is known of the relationships in this bathypelagic system except that its nutriment is sinking from above, with temporary capture within the system and ultimate loss of the unmetabolized profits to the benthos below. For that matter, the neritic-estuarine ecosystem of the Gulf Coast is incompletely understood; while we may recognize it by the abundance of penaeid shrimp, this does not mean that the shrimp are the dominant members in the sense that their presence determines the nature of the community and alters the substrate. Perhaps they do, but our present knowledge does not justify

[21] There appears to be a growing fashion for the appropriation (and consequent misuse) of ecological terminology by chemists and physicists. Such terms as "strontium ecosystem" (Odum, 1951), and "molecular ecology" are unwarranted extensions of biological concepts to essentially physical processes. The ecologist might, with equal license, consider "hydrologic cycle" as an ecological term. Incidentally, I wish to acknowledge my indebtedness to Martin D. Burkenroad for many clarifying suggestions in the preparation of this discussion.

the assumption. This is emphasized by the recent changes in the Gulf of Mexico; *Penaeus setiferus* has declined—or become economically less available to its principal predator, man, and the fisherman has replaced this loss with *P. aztecus* and *P. duorarum* by invading other parts of the ecosystem. Perhaps this change is a result of poor survival of young in the abnormally saline bay waters during recent drought years. If so, the ecosystem depends as much upon climatic factors on land as upon conditions in the sea, like the salmon complex of the north Pacific.

The origin of such a complex of environment and organisms is to be sought, not exclusively in the conditions as we find them today, but in the long periods of time which have moulded the environment and in turn enabled the selection of the organic types now existing in the environment. It does not seem that the fluctuations of the Pleistocene have been severe enough to destroy the organization necessary for the survival of this ecosystem, because so many of the marine organic and sedimentary facies of the Tertiary suggest that this system is the result of conditions developed in those times. Perhaps the dynamic conditions now obtaining were set in motion at the close of the Mesozoic with the passing of the dinosaurs from the land and the great hosts of shelled cephalopods from the seas and all that this implies in physical changes. The available evidence from the Cretaceous suggests that the region now bounded by the Gulf Coastal Plain has been in an area of transition between northern and southern environments since that time and such a constant state of ebb and flow of factors may be as stable an environment, from the standpoint of selection, as the apparently monotonous depths of the sea. As in sedimentation, as indicated by Lowman (1951), so in ecology is it difficult to interpret the Recent of the Gulf Coast without reference to the Tertiary, and *vice versa.* A case in point is the small number of endemic species—about 10% in most invertebrate groups—which may be a reflection of long continued environmental fluctuations which would enable the development of large populations of wide-ranging, adaptable species at the expense of the development of indigenous forms along the northern, neritic-estuarine coast. That such fluctuations occurred is also indicated by the cyclical character of Tertiary sedimentation.

It may be protested that it is of no particular advantage to say that the fauna is part of a system interrelated in a complex manner (which is obvious), and to assign to it a name satisfying the greatest possible number of generalizations, but it seems to me that "splitting" in ecology is far more dangerous than "lumping." The object is not to stress differences or to point out resemblances but to indicate the processes resulting in both faunal composition and mass, and the recognition of natural systems which reflect both climatic and biotic conditions as well as geological history should be an improvement over the semantic quagmire of associations and biomes which plagues some schools of ecology.

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Statement Concerning Editorship

Volume I, Number 1 of this journal was edited by Prof. E. J. Lund. For all subsequent issues, up to and including Volume III, Number 1, these duties were handled by the undersigned, acting in an *ex officio* capacity. Joel W. Hedgpeth assisted in editing Volume I, Number 2, and Martin D. Burkenroad assisted in editing Volume II, Numbers 1 and 2, and Volume III, Number 1. With this volume the writer assumed full editorship.

GORDON GUNTER
Director

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A Study of the Fauna of the Brown Shrimp (*Penaeus aztecus* Ives) Grounds in the Western Gulf of Mexico

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INTRODUCTION

The aims of this study are somewhat diverse. During the past few years a new shrimp fishery has developed for the brown shrimp, *Penaeus aztecus* Ives, in the western Gulf of Mexico. The fishery is confined to the shallow water over the continental shelf. American and Mexican fishermen land over two hundred million pounds of shrimp every year at Gulf ports. A major undertaking was the collection and compilation of information on the distribution and relative abundance of the animals taken in trawls in the brown shrimp fishery. This phase of the work extends the initial surveys of the fauna of the shallow Gulf and bay waters of Louisiana and Texas, made by Gunter from 1931 to 1942, to deeper Gulf waters. Specifically, such data are a necessary base for ecological studies and more generally they add considerably to the general picture of the fauna of the western Gulf. Additionally, certain life history and ecologic notes concerning various species have been collected. Information on the trawling grounds and areas and the catch per unit effort was compiled.

The region studied includes various localities in the northern Gulf from the mouth of the Mississippi River to 24° 10′ N. on the Mexican coast and an isolated but important shrimping ground off Alvaro Obregon in the Gulf of Campeche. Some fishing was done on the Campeche Banks for pink shrimp, *Penaeus duorarum* Burkenroad, but these data are not discussed in detail. Only brief excursions were made to the inshore, white shrimp, *Penaeus setiferus* (Linnaeus), fishing grounds to gather comparative material and to check on concentrations of young brown shrimp.

Most exploratory expeditions have not visited the western Gulf and relatively little is known of the fauna at depths greater than 10 fathoms. During the period from October 20, 1950 to September, 1951 the catches on commercial trawlers were examined by the writer in order to gather information on the relative abundance of the fishes and the larger invertebrates. One hundred and sixty-four trawl hauls were made on the brown and white shrimp grounds in the western Gulf. The depths fished ranged from 3 to 45 fathoms, but most trawling was concentrated in the 10 to 24 fathom zone. Sixty-one hauls were also completed on the pink shrimp grounds, Campeche Bank. These data concern a separate and quite different faunal complex, including the shrimp, and will not be treated in this paper.

Many adaptations in methods of collecting data had to be made to fit the conditions at hand. First, the writer was entirely dependent on the shrimp boats for transportation to and from the shrimping grounds. Although the boat captains were in all cases very amiable and cooperative, the writer was still a non-paying guest aboard the boat. No attempts were made to influence the captain's choice of locality or method of operation and no modifications of commercial shrimping practices were made on boats the writer was aboard.

The use of Aransas Pass as a base for a survey of the seasonal changes in the fauna of the bordering Gulf was found to be impractical. First, the catch drops drastically during the winter months on these grounds. The larger trawlers leave the area and the small trawlers that remain do not have space for observers. Secondly, the small trawlers are more dependent on favorable weather. Bad weather is not unusual during the winter, when the northers of fact and fiction chill the region and stop all shrimping for brief periods. The weather during the spring is, if anything, still more unsettled as the continental and Gulf air masses battle for supremacy.

The plan evolved was to follow the shrimp fleet in its migrations to the best shrimping grounds and, when an opportunity was found, to examine areas not fished by the main fleet.

METHODS AND EQUIPMENT

A fishing log was composed for the catch in each trawl haul and the limited amount of pertinent data that could be gathered from commercial operation.

No feasible method of taking bottom temperatures without interfering with the operation of the trawlers was found, so no attempts were made to gather these data. Springer (1952) states that there is a correlation between the bottom temperatures and the concentration of shrimp.

Another factor not analyzed was the effect of the tide and currents on the concentration of shrimp. Collier (1938) called attention to the importance of the tides in the life history and the fishery of the white shrimp, *Penaeus setiferus*. A few remarks by fishermen were copied in my field notes on this phenomenon, but no attempt was made to correlate catches directly with the tides. Captain Allen of the "San Jacinto" told the writer that the white shrimp moved inshore on a rising tide and offshore on a falling tide and I have observed boats moving in and out between 3 and 8 fathoms with the tide, particularly between Greens Bayou and the mouth of the Colorado River during October, 1950. Therefore, one would not be able to impute a uniform density of shrimp over the area involved if the same number of shrimp were caught in 8 fathoms in the morning that were caught in three or less fathoms in the late afternoon.

Only a few remarks were entered in the fishing log on the state of the sea. Some boat captains would risk the loss of gear in rough weather, while others considered it wiser and more profitable to return to port. What effect strong winds have on the shrimp fishery, besides reducing the number of shrimping days, has not been investigated, although there are many opinions among the fishermen. Most fishermen believe that heavy swells stir up the brown shrimp during the daytime, and thus permit fishing both day and night instead of a few hours at night. There are reports that the fishermen have trouble finding the schools of white shrimp after a strong wind.

The writer had no opportunity to make observations after a hurricane for none occurred during the period of this investigation. However, fishermen in the Gulf of Campeche and off the northeast coast of Mexico told the writer that after the hurricane of August, 1951, which crossed the Gulf of Campeche and went inland near Tampico, Mexico, no changes in the adundance or location of shrimp were noticeable. It is a widespread belief among fishermen that shallow water fishing and shrimping improve the year after a hurricane. A typical comment is the following one extracted from the report of the Texas Game, Fish and Oyster Commission for the fiscal year 1932–1933.

> The history of such storms is that fishing in the bays for the year following is extremely good. As a rule these tidal waves cut passes through the islands making egress and ingress easy between the bays and the gulf and tend to make the supply of fish more permanent. (Page 19.)

The date of full moon is recorded for each month of trawling. What influence the moon may have on the movement of shrimp other than its relationship to the tides is unknown. Many shrimpers state that fishing for brown shrimp is best during the full moon. However, others aver that with the increased number of boats operating in every part of the Gulf, the difference in catch is no longer very great. Brown shrimp can

often be taken in the daytime during the full moon, but whether it is, indeed, the causative factor is unknown.

The time of day that a drag was made and its duration was recorded in all cases. The long intervals between some drags were due to tearing or fouling of gear or movement to new fishing grounds. The length of a drag depended upon the personal inclination of the captain and the size of the catch expected, and drags varying from 25 minutes to 7 hours in length are recorded. Drags were always recorded to the nearest five minutes.

The type of bottom could be investigated with some degree of accuracy. Often the catch was covered with mud and it was necessary to leave the cod end of the net hanging in the water for a few minutes in order to wash the shrimp. If the sea was calm, the net would be towed a short distance at the surface of the water to wash the catch. Trawling for brown shrimp is carried out almost solely on mud bottom. These shrimp may also be caught on the shell bottom along the Texas coast, but the catch is usually too low to warrant the extra wear and tear on the net.

All major snags and other factors that reduce trawling efficiency were recorded. Most of the snags were probably due to coral, rocks or "mudlumps." In one doubtful case, the tear may have been caused by an accumulation of large conchs of the genus, *Busycon.* Often when a net was badly torn it was noted immediately and hauled aboard; if the cod end was undamaged the catch was as great as in a normal trawl haul. Other reasons for the fouling of nets were gear failures or human error. Another very important reason why the net sometimes came up empty is that sharks had torn holes in the bag.

No navigation equipment was used on any of the boats except a compass and a fathometer. All depths were determined by the fathometer except on three boats, "Francis Lee," "Alexandra C" and the "40 Fathoms No. 34." These boats had no fathometers. However, fishing was on well-known grounds and there is little probability of errors in the estimated depths. All areas of trawling are dead reckoning positions except in a few instances where landmarks or buoys were plainly visible.

Compass courses are only approximate as the captains usually follow a fathom contour rather than a compass course. A varied course means that the boat changed course at least once along the fathom curve. When a favorable shrimping ground was located, the captains often trawled in one direction for half the drag and then reversed their course and trawled back over nearly the same grounds. If the "spot" of shrimp was very small, he might reverse his course four or five times during a single drag. In this connection trawling over the same ground does not seem to decrease the catch appreciably. One fisherman stated that he even increased the catch by pulling a 35 foot net in front of the standard trawl.

The number of boats operating in an area was recorded by counting the number of running lights that could be seen at one time from the deck. The number varied from no boats seen for two days during May to a maximum of 66 in July.

A problem was raised by the operation of a large number of boats in a single locality, where there was the possibility of recapturing dead fish dumped overboard by other boats or your own boat. There was little evidence of such capture in deep water, such as the landing of shrimp heads or damaged fish. This factor can be ignored in deep water trawling, but it is an important point to consider when many boats are operating in shallow water.

The gear used will not be described in detail. Generally the gear was the standard Texas flat net (otter trawl) with the main variation being in the footrope. The footrope was sometimes leaded or the leads replaced by a jumper chain that is usually tied six to eleven inches in advance of the footrope. The size and weight of the doors varied, but this information was not gathered in all cases. Fishing qualities differ considerably from one net to another. Boat captains often make changes in the set of the doors, add additional weights to the doors, or change the setting of the "jumper chain" to improve fishing qualities of the gear. Consequently, there is no standard gear even during a single fishing trip.

Information on the boats from which the writer worked are given below. The data were supplied in most instances by the boat captains.

"San Jacinto"
Wood construction
Length 62.5 ft.
Beam 21.05 ft.
Engine Caterpillar Diesel 130 Hp.
Net 120 ft.; leaded footrope

"Rio Bravo"
Steel construction
Length 69 ft.
Beam 19 ft. 10 inches
Engines Twin Gray Marine Diesels 165 Hp. each
Net 120; jumper chain

"Gypsy Girl"
Steel construction
Length 61.8 ft.
Beam 18.8 ft.
Engine General Motors 165 Hp.
Net 120 ft.; leaded footrope

"Dr. Billy"
Wood construction
Length 57 ft.
Width 17 ft.
Engine General Motors 300 Hp.
Net 120 ft.; leaded footrope
Doors 12 ft. long 40 inches wide

"Sabine No. 1"
Steel construction
Length 65 ft.
Beam 21 ft.
Engines 2 General Motors 165 Hp. each
Net 135 ft.; jumper chain
Door 12 ft. long 58 inches wide
Refrigerated, 300 barrels capacity including brine tank storage

"Capt. George Hamilton"
Wood construction
Length 55 ft.
Beam 15 ft.
Engine General Motors 165 Hp.
Net 120 ft. (March trip); 96 ft. net (May trip);
105 ft. net (July trip); leaded footrope
Doors 12 ft. 46 inches

"Francis Lee"
Steel construction
Length 58 ft.
Width 14 ft.
Engine Caterpillar 130 Hp.
Net 96 ft.; jumper chain
Doors 12 ft. 44 inches

"Alexandra C"
Wood construction
Length 43 ft.
Beam 15 ft.
Engine Caterpillar 88
Net 65 ft. leaded footrope

"Forty Fathom No. 34"
Wood construction
Length 50 ft.
Width 15 ft.
Engine Cummins 145 Hp.
Net 120 ft.; jumper chain
Door 12 ft. 40 inches

"Mister Mac"
Wood construction
Length 60 ft.
Beam 19 ft.
Engine General Motors 165 Hp.
Net 120 ft.; leaded footrope
Doors 12 ft. 48 inches

"Texas Clipper"
Steel construction
Length 66 ft.
Beam 20 ft.
Engines 2 General Motors 165 Hp. each
Net 120 ft.; jumper chain
Doors 14 ft. by 48 inches

No definite time of the month could be scheduled for trips to the shrimping grounds because of the variability of the weather. Usually I went to the port nearest to the shrimping grounds that I desired to visit without any advance arrangements for passage and always looked for high producing boats. If a suitable boat was in port, the captain was approached for permission to make a trip to the fishing grounds. No difficulties were experienced in getting permission, but I spent up to fifteen days waiting for suitable weather and a boat that was going to the fishing grounds.

No definite time limits have been set on the length of time that a boat can stay away from port. Of course, there is a practical limit governed by the keeping qualities of the shrimp. If one is dependent on commercial trawlers, he must be prepared to stay out from one night or a maximum of 15 nights in the northern Gulf. A trip to the Campeche banks will last about 20 days, while a refrigerated trawler may stretch this time to two months. Such an itinerant observer must also be resigned to following the areas of best shrimping and he may come into port a hundred miles from the point of departure.

Very little equipment was carried by the writer. It consisted of a milk can for preserving specimens, a measuring board, pencil and paper. Water-proof sheets of a white plastic were used for recording. This worked very well in fish slime and sea water. After the data were copied onto the main log, the sheets could be washed with a washing powder and re-used.

There are practical limits to the information that can be gathered on commercial shrimp boats for the crew always wants to clear the deck as rapidly as possible. All specimens could not be counted or each species weighed separately, for the catch had to be sorted before the next load came aboard.

The October trip was used to become acquainted with the fauna and fishing methods and only a few observations on the relative abundance of animals in the trawls were recorded. I decided that the best method was to count all the larger fishes such as sharks and rays in all drags. This was also possible for large and conspicuous crabs as *Calappa springeri* and a few other animals which appeared only rarely or in small numbers. Shrimp of commercial size were originally recorded by the basket, and on landing the total weight of shrimp caught was obtained in nearly all cases. The remaining species caught in the trawls were recorded as to species in all 164 drags, but in 90 drags the abundance of individual species was determined by counting a portion of the catch. The portion of the catch counted depended on the size of the catch and the counts varied from one-half to 1/100th of the catch. Estimates of the portion counted were checked in several ways. One method was to compare the number of commercial shrimp in the sample with the total number in the drag. The other method was a comparison of the number of shovels of trash in the sample with the number in the catch.

When only a small percentage of the total catch is counted, a fish might be rare, but the few specimens present might fall in the counted portion. Such cases were adjusted by the writer's estimates, which he made after personally sorting one-half to one-tenth of every drag. A further check was provided on the species present by casually examining the catch before any sorting started, and an additional examination of the trash before it is pushed overboard. It is probable that nearly all the species present in each drag were recorded. A fair estimate of their relative abundance, as related to the gear used, was obtained.

Only a few measurements were recorded and most of these were to show the range of size rather than the mode of the populations. All measurements of fishes are fork lengths, *i.e.* the fish was measured from the tip of the snout to the midpoint of the tail.

Field identifications were checked by making a preserved collection. Nearly 2,000 fish were collected in the area of the brown shrimp fishery, and an additional 580 were collected from Campeche Bank. In a few cases it was found by checking preserved specimens that the proper separation had not been made between two related species, such as among the young of the Synodontidae. In such cases the data were grouped.

There are many defects in using only an hour of trawling as the unit of fishing effort. However, it has one definite advantage in that it can be accurately measured. No work has been done on the fishing characteristics of a shrimp trawl. How wide an area does a shrimp trawl sweep effectively? Does it vary when the net is empty and when it is full and by how much? The writer used a subjective figure or 80 per cent of the footrope length as the effective fishing width. Still another assumption had to be made as to the trawling speed of shrimp vessels. I have chosen two and one-half knots as the average speed because most fishing captains made estimates of two and one-half knots. Shrimp fishermen often trawl back and forth on a fishing ground, so the effects of the current are probably closely balanced, that is to say, what is gained by trawling with the current is again lost when the boat returns over nearly the same grounds.

AREAS FISHED

The Gulf of Mexico is an oval or kidney-shaped basin. It is approximately a thousand miles wide from east to west. From north to south, between the Delta of the Mississippi and the north coast of Yucatan, it is approximately 500 miles across the Gulf. The distance between the coast of Tabasco and Sabine, Texas, is approximately 750 miles. In this paper the western Gulf is defined as the area west of the meridian between the Delta of the Mississippi and the north coast of Yucatan. Such a meridian is a convenient geographical boundary and has some biological significance at least in the northern part of the Gulf, as the influence of the Mississippi River is greater to the west than to the east of the Delta.

Economically there is little reason to divide the Gulf into eastern and western areas. One of the oldest fisheries on the Gulf coast is located in Pensacola, Florida, and snapper fishermen have for years traveled to and from Campeche Bank. Recently more shrimp from Campeche Bank have been landed at southern Florida ports than in Texas. Nowadays the shrimp fleet is highly migratory, and fishermen may fish extensively both in the eastern and western Gulf during the course of a single year.

All four species of shrimp now commercially exploited in the Gulf of Mexico are caught on the continental shelf. For example, the seabob, *Xiphopeneus krøyeri* is restricted to a very narrow zone near shore, and it is rarely if ever abundant beyond ten fathoms. *Penaeus aztecus* lives from the bays to 63 fathoms in depth, and it is not uncommon 100 miles from shore. The writer estimated that at least 98 per cent of the commercial landings consist of shrimp caught inside the 35 fathom contour and at least 90 per cent were caught inside the 25 fathom contour during 1951. The percentages of shrimp caught at different depths would vary with the relative abundance of the four commercial species. The 1951 catch of white shrimp, *Penaeus setiferus,* in Texas was about 30 per cent of the 1943 catch. This indicates a serious decline in abundance in

an area that is normally fished for white shrimp. Therefore, fishermen were forced to fish more in deeper water or stop fishing. In this paper, only the open Gulf beyond the outer beaches of the barrier islands will be discussed, although the prime importance of the inner bays and estuaries as a nursery ground for the genus, *Penaeus*, is recognized.

Structurally, the continental shelf should be considered a part of the bordering coastal plain. The continental shelf varies greatly in width. It is approximately 120 miles wide off Cameron, Louisiana. In Texas it has an average width of sixty miles and is much wider off Sabine than off Port Isabel, Texas. The slope of the Texas coastal plain is about five feet to the mile and the slope of the continental shelf is about twelve feet to the mile (see Carsey, 1950). The average width of the shelf off Tamaulipas, while it was not calculated, is considerably less than off Texas. Off Punta Roca Partida in the State of Vera Cruz, Mexico, where the Eastern Sierra Madre Mountains almost reach the coast, the continental shelf is correspondingly narrow and steep, being approximately eight miles wide. In the vicinity of Campeche, Mexico, the shelf is ninety miles wide, and the abrupt seaward escarpment of Campeche Bank is probably due to down-faulting (Weaver, 1950).

If the twenty fathom curve is considered the mid-depth of the brown shrimp fishing grounds, a fisherman would have to travel seventy miles from Cameron, Louisiana, or nearly nine hours by shrimp boat to reach it, but the distance would be only two miles off Punta Roca Partida. If the continental shelf was a smooth area, everywhere suitable for the operation of the otter trawl, it would be much simpler to map the concentrations of shrimp. The abundance of shrimp in areas not suitable to trawling can only be surmised.

1. White Shrimp, *Penaeus setiferus* (Linnaeus), Fishing Grounds.

A distributional map of *Penæus setiferus* in the Gulf of Mexico has been published by Springer (1952). This map is somewhat misleading. In the first place the range of white shrimp is shown as continuous and no weight is given to depth concentrations. Although white shrimp have been recorded in 43 fathoms of water off Louisiana, commercial trawling is concentrated inside 20 fathoms, and indeed the bulk of the catch is made inside 14 fathoms. There are seasonal variations in the depths where white shrimp occur and the tagging of shrimp has shown that they move offshore in the winter in Louisiana (Higgins, 1937). Furthermore, the reports of commercial fishermen and my investigations indicate that the white shrimp, in contrast to Louisiana, is restricted to a narrower vertical range on the south Texas coast and off Tamaulipas. Commercial quantities of white shrimp are not found at depths greater than 17 fathoms off Padre Island. However, fishermen report that white shrimp occur in commercial quantities in deeper water off the coast of Tabasco and Campeche than off Padre Island. The following discussion is primarily concerned with trawling conditions and not with relative productivity of the different grounds. Production varies greatly from year to year and seasonally; often most of the shrimp are caught in very small areas.

The largest single fishing ground for white shrimp is the territory from the mouth of the Mississippi River to Freeport, Texas. Almost all the bottom inside 14 fathoms is clear and suitable for trawling except for Sabine and Heald Bank and the vicinity of wrecks and snapper banks. There are also regions of soft mud, such as off Timbalier

Pass and the Atchafalaya River, and extensive amounts of shell in 8 to 14 fathoms off Sabine, but either these hazards are not extensive, or they do not hinder fishing with modern gear.

Between nine fathoms and the shore there are numerous obstacles to trawling in the region from Freeport to the Colorado River. Numerous snags and large amounts of soft mud ("suck sand") make fishing virtually impossible except in small prescribed areas. These small pockets are very productive at times, but even the most experienced local fisherman sometimes loses gear. Presumably the Colorado and the Brazos Rivers deposit logs and mud which make this locality unsuitable for trawling.

Paralleling the coast from the Colorado River to about 27° N. is a belt of bottom inside 14 fathoms that is suitable for trawling. There are very few hazards to trawling in this region.

From about 27° N. to ten miles south of the Rio Grande there is an area that is unsuitable for trawling because of soft mud, coral, shell and topographic irregularities. At 26° 48′ N. are found the small finger-like ridges and valleys discussed by Mattison (1948). Some of these ridges are reputedly topped by dead coral. Much of the ground off Port Isabel, according to the fishermen, is covered with prickly conch, *Murex fulvescens*, and other shell. Shell bottom can be trawled, but net damage is much greater than on mud or sand bottoms. A few patches of clear bottom are present, such as around the whistling buoy and a small tract along the beach about 15 miles north of Port Isabel. Fishermen with small boats and small nets fished much more of the inshore area in former years than is now fished by the large trawlers.

The grounds along the east coast of Mexico suitable for white shrimp trawling are equal to about one-tenth of the white shrimp grounds in the Louisiana–Texas area. In part this is due to the much narrower continental shelf, but there are also large areas of coral, volcanic rocks and soft mud.

Generally the production of white shrimp along the northern coast of Tamaulipas is very small, although fishermen in the Port Isabel area report that a run of white shrimp occurs about once every ten years. Presumably these fluctuations are caused by changes in the hydrographic condition of Laguna Madre del San Antonio, the only extensive nursery ground along the coast. There is a small stretch of trawlable bottom that begins about ten miles south of the Rio Grande and extends about 70 miles down the coast. From this ground to Tampico the bottom is marked as hard on the hydrographic charts. According to Texas fishermen it is rough and covered with prickly conchs. Presumably "pockets" could be trawled, and indeed an extensive area near the Tampico Light produces shrimp. From Tampico to Tuxpan there is very little trawling ground. Near Cabo Rojo a few white shrimp are caught.

In the State of Vera Cruz there is a small area of good bottom known to the Texas fishermen as the Nautla grounds. As far as is known only the immediate surroundings of the estuaries of the Tuxpan, Tecolutla and Nautla Rivers are suitable for trawling. A little trawling is done off Alvarado, Vera Cruz.

No other offshore white shrimp fishery has been developed along the Mexican coast this side of Obregon although a small area can be trawled near Laguna Carmen. The most important white shrimp fishing ground in Mexico lies off the coast of Tabasco and Campeche. Only the area of highest production is delineated in Figure 1. Additional ground is trawlable, but production is usually low, although occasionally large

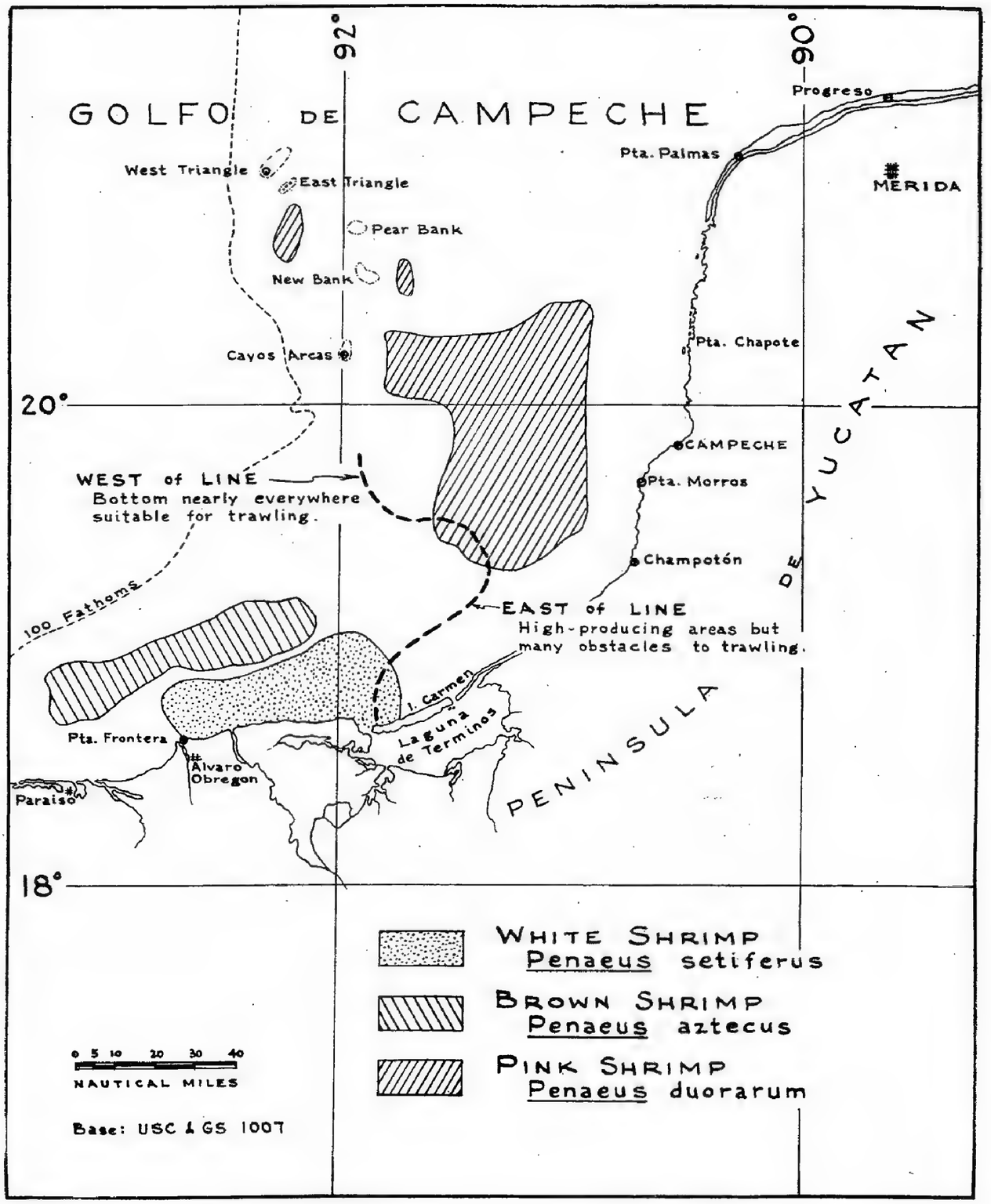

FIGURE 1. Shrimping Grounds in the Gulf of Campeche.

concentrations of white shrimp are encountered on the pink shrimp *(Penaeus duorarum)* grounds to the east. Production is reported to be very slight in the area west of Punta Buey, where the hydrographic charts show a shell bottom.

During my investigation I visited only a small portion of the white shrimp grounds described in the preceding paragraphs. A few drags were completed between Pass Cavallo and the Colorado River, a few off Sabine, Texas, and several in 12 to 14 fathoms off Wine Island Pass in Louisiana.

2. Brown Shrimp, *Penaeus aztecus*, Fishing Grounds

The chief fishing grounds for the brown shrimp, *Penaeus aztecus*, are delineated in the accompanying figures. The information on which these maps are based was supplied by commercial fishermen. The fishery for the small brown shrimp in the protected waters of the bays and in depths of less than twelve fathoms has been ignored. There are no separate statistics on this part of the fishery, but large landings are made in Louisiana and East Texas. I saw loads of 40–65 count brown shrimp in the fish houses from Seadrift to Sabine, Texas, during late May and June, 1951. There were mixed loads of small white and brown shrimp being unloaded at Grand Isle, Louisiana, during June, 1951.

There is an important ground for brown shrimp off Southwest Pass at the mouth of the Mississippi River. However, trawling conditions are for the most part abominable and the returns are small compared with the rich 24–10 beds, so that many fishermen have emigrated with their large trawlers to Port Isabel. New interest was shown in the Southwest Pass ground when the fleet became so large in Port Isabel that the catch per boat became less than catches off Southwest Pass. Springer (1951) suggests that this fishery developed because of the discoveries of the "Oregon," but the presence of brown shrimp there has long been known. The area regularly fished for brown shrimp has expanded considerably since 1951 when it included about 420,000 acres near Southwest Pass. However, not all this bottom is trawlable and much gear has been lost in soft mud and "mud lumps."

Shaw (1914) described mud lumps as domes of fine, tough, structureless clay rising two to ten feet in height usually within a mile or two of the end of the passes of the Mississippi River. Fenneman (1938) favored the theory that thin layers of highly mobile clay under the pressure of accumulating sediments on the delta are caused to flow laterally and break through to the surface at favorable points. Whether the mud lumps, as used in the Gulf fishermen's vocabulary, are the same type as the ones studied by Shaw, is not known. Fishermen have used this term to describe trawling conditions 60 to 70 miles from land. Springer (1952) identifies "mud lumps" as soft mud bottom.

Another bottom type is the soft gooey mud of the Delta region and offshore in East Texas. Possibly this condition is synonymous with the so-called "suck sand" found off the Colorado River and on Campeche Bank. Often an entire rig is lost when such trawling conditions are encountered.

From Southwest Pass to the submarine canyon, a distance of approximately 20 nautical miles, there is considerable trawling in depths of 40 to 55 fathoms. All other major brown shrimp grounds in the western Gulf of Mexico are in shallower water. The Southwest Pass grounds continue westward from the submarine canyon in depths of 12 to 29 fathoms to the shell ridge off Big Constance Bayou. In this part of the Southwest Pass grounds there are obstacles to trawling such as dynamited wrecks south of Ship Shoal and the extensive area of soft, gooey mud south of Trinity Shoal. Some of the soft mud bottom off Trinity Shoal is fished by wrapping the footrope of the trawl until it is a foot or more in diameter. Many places on the Southwest Pass grounds in former years were seasonally fished for large white shrimp, and it is probably on these grounds that there is the greatest interspecific competition between the adult white and brown shrimp.

Prior to the summer of 1953 the vast area from Big Constance Bayou to the Colorado River was not fished for brown shrimp, and it was stated that there was very little

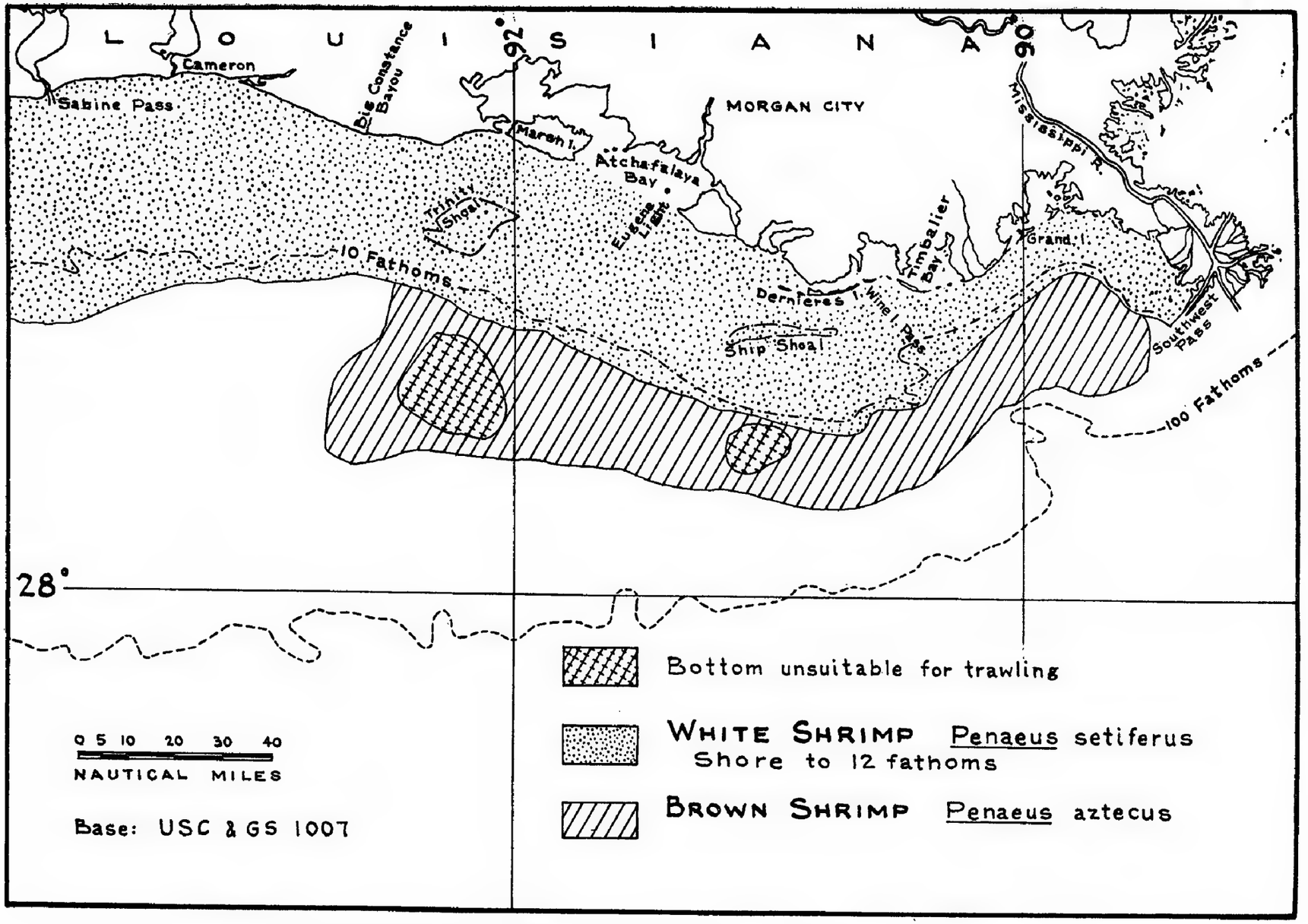

FIGURE 2. Southwest Pass Grounds and shrimping grounds in western Louisiana.

bottom suitable for trawling because of an extensive shell ridge, snapper banks and soft mud. A few brown shrimp were caught off Freeport in 14 to 17 fathoms, and small brown shrimp were caught inshore of the 12 fathom contour. Most of the landings of brown shrimp at Freeport, Texas, were caught off Pass Cavallo or off Obregon, Mexico. Active exploration in the area east of the Colorado River was carried out by the shrimping fleet during the summer of 1953, and the largest catches per unit of effort were made in that area. Most of the fishing was done in depths of 14 to 17 fathoms from Freeport to Sabine. Some fishing was done in 19 fathoms southeast of Freeport and some bottom was reported in deeper water. One of the big disadvantages of this area is the great distance from shore that the boats must work; consequently there was very little winter fishing in the area.

The following section of the bottom types off Sabine was supplied by M. J. Broussard, and it has been confirmed by other fishermen.

1. Beach to 8 fathoms. Sand, mud and some shell, but the bottom is clear and suitable for trawling except for Sabine Bank, a rocky area.
2. Eight to 18 fathoms. Shell, mostly prickly conchs, *Murex fulvescens* and *Strombus alatus*.
3. Eighteen to 20 fathoms. Mud bottom (some trawling can be done here but it is 8 to 9 hours running time from Sabine).
4. Twenty fathoms on out. Too many mud lumps for trawling. Fishermen have lost nets in 27 fathoms off Sabine, where bottom looked clear on the fathometer, but the nets sank into the soft mud.

The snapper fishery is most diligently prosecuted in the area from Ship Shoal, Louisiana, to the Claypile and Heald Bank off Freeport. Many of these snapper banks are topographic heights that have been called salt domes by some geologists. Snapper fishermen report that they often find large brown shrimp in the stomachs of snappers.

The largest single area of trawlable bottom for brown shrimp is what I have named the Texas ground. This fishing ground extends from the Colorado River to Sebree Bank about 30 miles north of Port Isabel. Although the entire region from 12 to 50 fathoms is suitable for trawling, it has been divided into two parts with the 28 fathom contour as the dividing line. The reason for this is that the 28 to 29 fathom contours mark the seaward limit of the most profitable fishing.

Between 12 and 25 fathoms on the Texas grounds there are an estimated 2,700,000 acres suitable for trawling. The bottom type is predominantly mud, and only a few snapper banks and wrecks hinder trawling. Possibly the most extensive area of bad bottom is in the 17½ to 20 fathom zone off Pass Cavallo. At its northeastern edge the mud bottom is replaced by shell and the fishery is relatively unproductive in this region. The southern edge is highly irregular and narrow belts of trawlable bottom link it with the 24–10 grounds to the south. Snapper banks and shell occur along the south edge of the Texas grounds.

As previously mentioned, the present seaward limit is prescribed by the productivity of the grounds, *i.e.* the trawlable bottom beyond 29 fathoms produces less shrimp per hour of trawling than the inshore grounds. Nevertheless, there is some trawling in 29 to 50 fathoms, but the area is not well known to most Texas fishermen, and gear is lost because of the ignorance of trawling hazards. There are a number of snapper banks in this district, notably the ones in 41 fathoms off Aransas Pass. Although the extent of

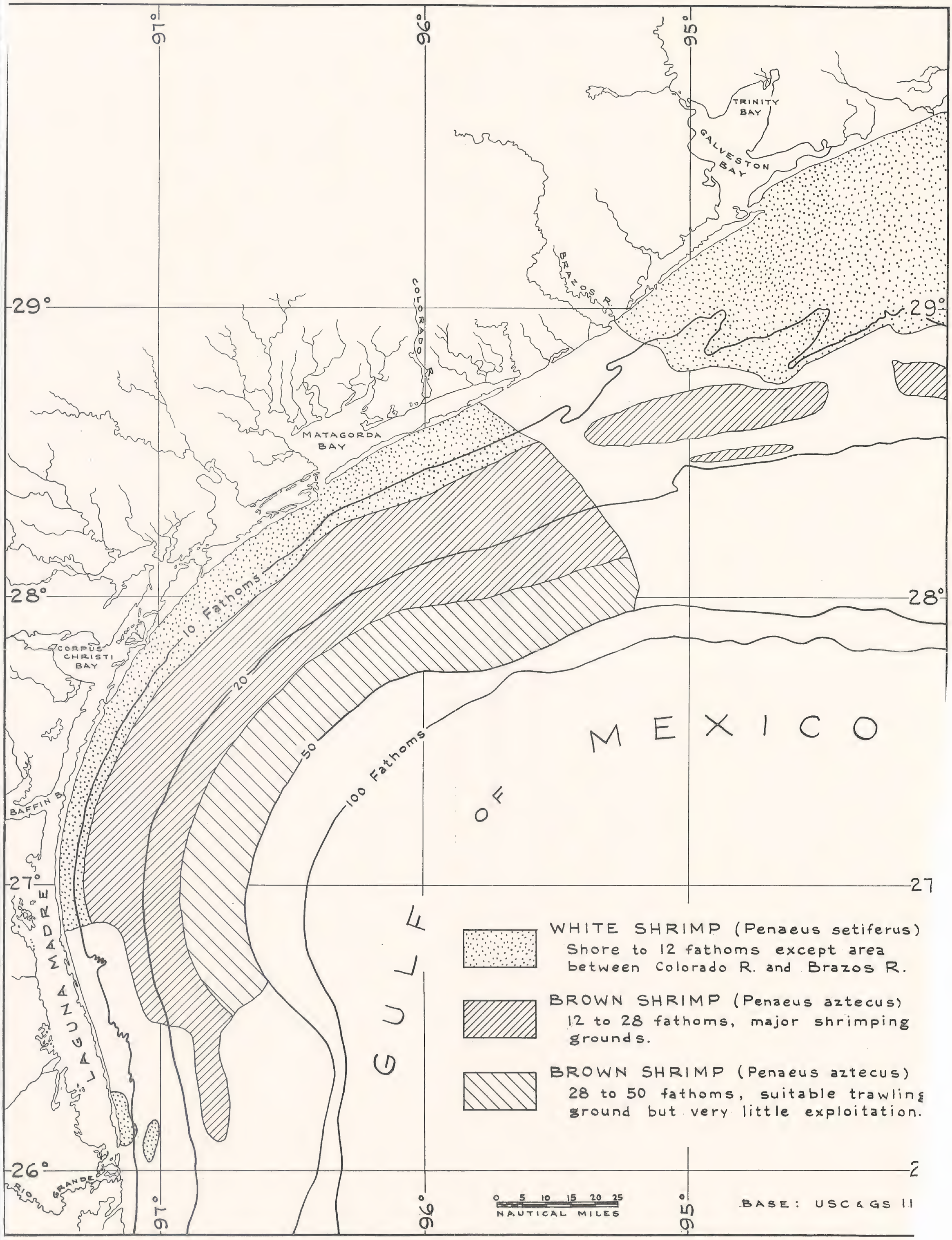

FIGURE 3. Texas Grounds.

trawlable bottom is undoubtedly large, no estimates of the area involved were made because little is known about the bottom.

From Sebree Bank to about 20 miles below the Rio Grande, there is an area that is not fished regularly. The bottom is rough and there are locally large concentrations of shell and sand dollars. These obstacles plus the snapper banks discourage most fishermen from trawling here. Some trawling is done at depths of 24, 32–33 and in 35 fathoms.

The next important ground is what I have called the 24–10 ground after its most productive portion. This fishing ground extends from about 20 miles below the Rio Grande to northeast of Sugarloaf Mountain at approximately 23° 15′ N. From Sugarloaf Mountain southward to Punta Jerez, there are small "pockets" of trawlable ground that should be included. There are an estimated 2,300,000 acres of trawlable bottom in the 24–10 ground. The fishery is concentrated between 12 and 40 fathoms, except in the region of 24° 10′ N. where rocks (probably igneous in origin) extend out to 27 fathoms. The depth of the fishery varies seasonally, and the bulk of the winter and spring catches are made in depths of 30 to 40 fathoms. A number of trawling conditions are encountered in the area. Most of the bottom is mud, some of it is soft mud and a small part is shell.

Between Punta Jerez and Lobos Island the bottom is rocky. Coral and volcanic necks hinder trawling. The known shrimp grounds consist of "pockets" of trawlable bottom. Occasionally, a few large catches from this area are unloaded in Port Isabel.

The next locality of importance is the Lobos Island ground, where a small fishery has been developed about 10 miles south of the island. The chief pockets of trawlable bottom are in 16–17, 25–26 and 34–36 fathoms, and most of the trawlable bottom, according to the fishermen, is reddish mud. Although this fishing ground has been known to Texas fishermen since the days of extensive exploration along the Mexican coast during 1947–50, it was not intensively fished until the spring of 1953. Perhaps the heavy run during 1953 was, indeed, greater than in previous years as some fishermen think, and it may well have been related to the decreased runoff and rainfall on the nursery grounds in Laguna Tamiahua. I did not visit the Lobos Island ground, although I did examine a small collection of fish from the area. This collection closely resembled the fish fauna of the Obregon ground. Fishermen report that they catch nearly "clean shrimp," *i.e.*, very few fish or invertebrates are caught.

Between the Lobos Island ground and Obregon, no important brown shrimp grounds exist, although there are pockets of trawlable bottom at least as far as Alvarado. One of the largest of these pockets is in 22–35 fathoms east of Alvarado.

The Obregon ground is delineated in Figure 1. It consists of about 800,000 acres of productive bottom. Mud is the predominant type of bottom and the grounds were found to be surprisingly free of shell during my investigations in 1951. The limits of this fishery are prescribed by small populations of shrimp on the neighboring grounds rather than trawlable bottoms. Some brown shrimp are caught as far east as Champoton, the west boundary of the pink shrimp grounds, but this fishery developed after catches fell on neighboring pink and brown shrimp grounds. The west boundary is a shell ridge that runs offshore from Chiltepec. At times, a few shrimp are caught in 23–26 fathoms in the area between the Chiltepec shell ridge and Laguna Carmen.

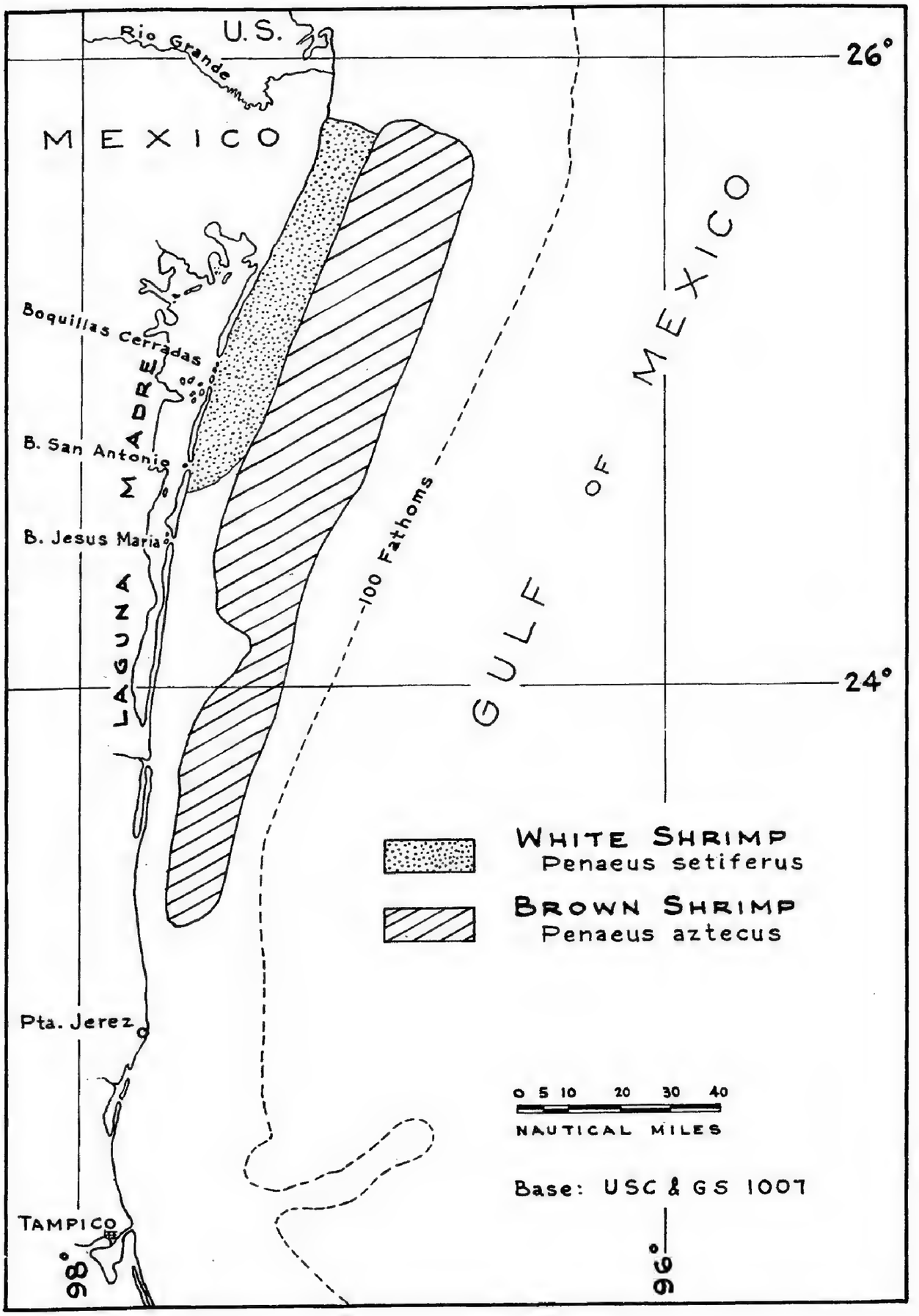

FIGURE 4. 24–10 Grounds.

The main brown shrimp grounds as described in the preceding paragraphs are as follows:

Grounds	Estimated Trawlable Area Acres
Southwest Pass Ground	1,800,000
Texas Ground (main region)	2,700,000
24–10 Ground	2,300,000
Lobos Island Ground	25,000
Obregon Ground	800,000

3. Pink Shrimp, *Penaeus duorarum*, Fishing Grounds

The pink shrimp occur as juveniles in the bays of Texas, and a few adults, less than one per cent of the total catch, are captured along the coast. Sometimes in the spring of the year a large number of small spotted (pink) shrimp are captured, according to fishermen's reports, in depths of less than 20 fathoms along the Texas coast. This was especially true during the spring of 1954.

The only pink shrimp ground of importance in the western Gulf is off the coast of Campeche. Numerous conchs, large loggerhead sponges, coral and rough bottom plague the shrimp fishermen in this region, but much of the area outlined in Figure 1 can be trawled. The pink shrimp has an ecological preference for shell sand rather than the mud bottom on which the brown shrimp thrive. Most of the pink shrimp fishery is concentrated in depths of 4 to 25 fathoms.

DISCUSSION OF THE FAUNA BY SPECIES

Invertebrata

The large trawls and the trynets used in this investigation are not suitable for capturing many of the smaller invertebrates and no special attention was paid to small species which only rarely entered the catch. It is necessary to realize the limitations of the gear used before evaluating the data in accompanying tables. The tables are based for the most part on the large trawl catches. While a large number of trynet catches were examined, they were searched particularly for animals not appearing in the large trawl and often no record was made of the common organisms. Some animals appeared only rarely in the large trawl, yet the trynet catches revealed evidence of a large population.

Anthozoa

Alcyonaria

Pennatulacea

Renillidae

Renilla mulleri Kolliker

Sea pansies are recorded in only five drags, if the month of October is not included. Sea pansies were captured slightly more frequently in the trynet but no systematic attempt was made to record trynet catches.

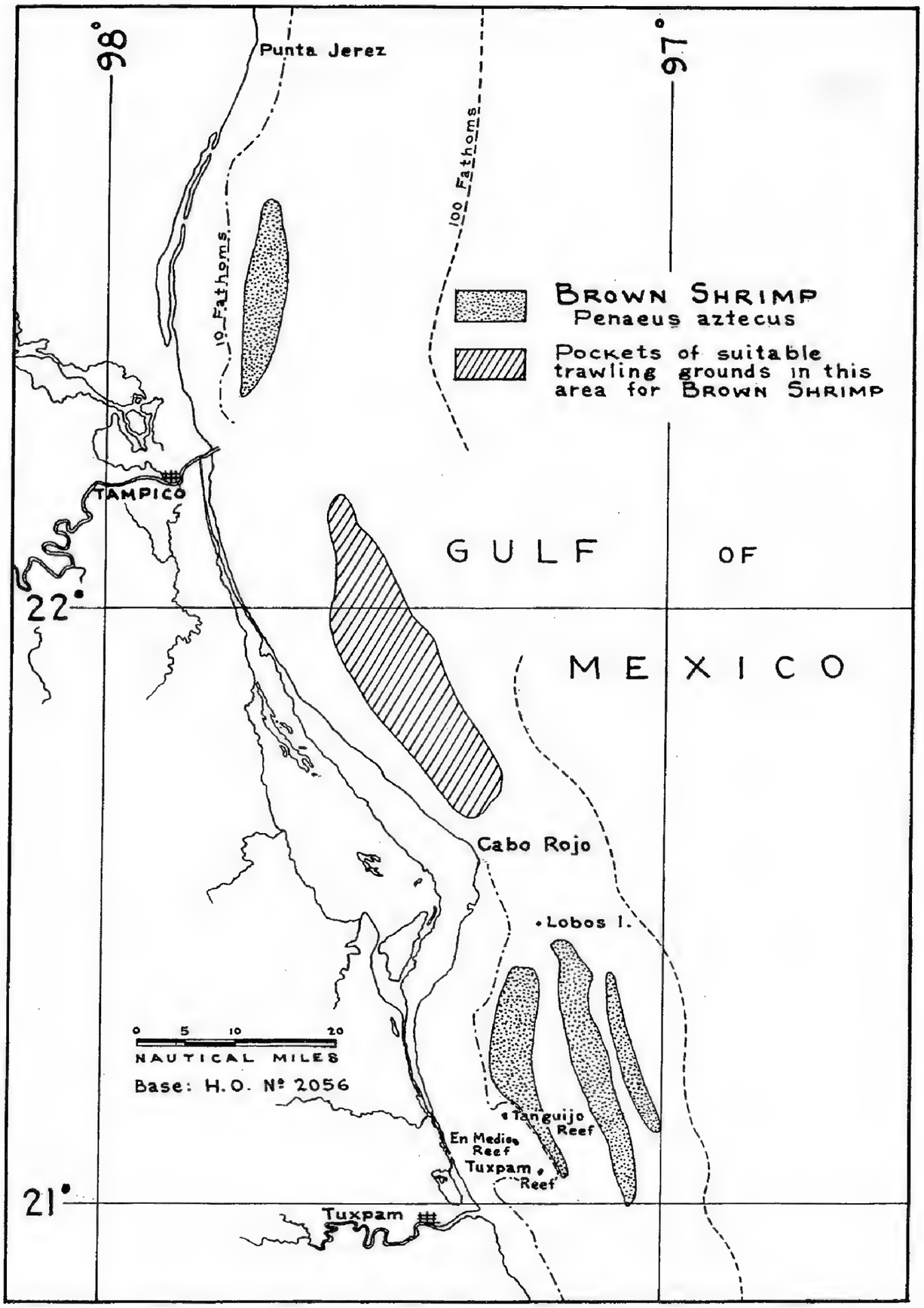

FIGURE 5. Lobos Island Grounds.

Several peculiarities were noted in its geographical distribution. On May 5, 1951 several dozen were dumped on deck from a 15-minute trynet haul in ten fathoms off Aransas Pass jetties. The bottom was mud. On May 11, 1951 only four specimens of *Renilla* were taken in a 30-minute trynet haul in 11 fathoms on shell bottom east of Freeport, Texas. No specimens were recorded from Sabine, Texas in depths of 3 to 6½ fathoms, nor was it taken off Grand Isle in depths of 12 to 24 fathoms. That its absence in the Grand Isle region is not due to limited collecting is indicated by the work of Behre (1950) who does not list it in her fauna of Grand Isle. Bayer (1952), however, lists it from the other side of the delta within six miles of Pass à la Loutre. This species seems to be present in shallow waters of high salinity.

Several specimens were taken on the Obregon Grounds and off northeastern Mexico, so it has a wide distribution in the western Gulf. The bathymetric distribution of the sea pansy on the Texas coast has been discussed by Gunter (1950). He found that it was abundant out to 15 fathoms, and lists it as the most common invertebrate taken in trawls in the shallow Gulf, except for the white shrimp, *P. setiferus*. He said shrimp trawlers sweep in thousands daily, but this referred to the time before development of the brown shrimp fishery and trawling farther offshore. There are no indications of an abundant population beyond 15 fathoms. The deepest that it was recorded was in 21 fathoms about 60 miles south of the Rio Grande. A few specimens were taken in 16½ to 20 fathoms a few miles north of Sebree Bank.

Virgularidae

Virgularia mirabilis (Linnaeus)

One specimen 56 cm. long was taken in 18 fathoms south southwest of Freeport, Texas. This octocoral is well known to the Freeport fishermen, who call it the "pipe cleaner." It appears to be predominantly a shallow water octocoral on the Texas coast as occasional specimens are found washed ashore on the outer beaches.

Actinaria

Hormathiidae

Calliactis tricolor (LeSueur)

This is the common conspicuous sea anemone on the shrimp grounds in the western Gulf of Mexico. My records extend from Grand Isle to Obregon, Mexico. No abundance records were taken, but it was usually attached to large *Busycon* or other large shells containing the big red hermit crab, *Petrochirus bahamensis*. It was also found attached to *Hepatus epheliticus* and three specimens were attached to a decorator crab, *Stenocionops furcata*. I obtained a specimen from 24 fathoms (the deepest trawled) off the Texas coast and Hedgpeth obtained a specimen in a tide pool (Carlgren and Hedgpeth, 1952).

Mollusca

A dredge would have been much better gear for taking mollusks than an otter trawl, as only surface living forms or shallow burrowing mollusks are taken in trawls. Large

numbers of shells are seldom observed in shrimp trawls along the Texas coast, for the shrimp fishermen do not fish the "shell piles." However, shells are so numerous on parts of the Campeche Bank that trawling would be difficult without a "jumper chain." During this investigation some drags were made on mud bottom without finding a single shell. This was particularly true off Obregon, Mexico. Certain shells were present in trynet hauls with almost monotonous regularity, yet they rarely appeared in the big net.

It was not always feasible to check all the snail shells to see if they were alive, so the method used was to count all whole, relatively unworn shells. At times observations of hermit crabs were included in the fishing log.

One other factor should be mentioned. Fishermen often move from one locality to another and trash captured on one fishing ground may be partially sorted and discarded on another, so there is the possibility of shallow water shells being dumped in deeper water or the reverse. However, the catch is sorted as fast as possible and undoubtedly very few mollusks are scattered beyond their normal bathymetric distribution. Occasionally, mollusks which were caught on Campeche Bank may be dumped overboard in the northern Gulf. No exotic species from the southern Gulf coast could have become abundantly established on the Texas coast during this investigation, as the fishermen had been fishing Campeche Bank for less than a year. Some dead shells may be scattered by currents. The writer obtained two old blackened apple snails off the mouth of the Grijalva River in 13 to 19 fathoms.

Pelecypoda

Arcidae

There are eleven species of this family known to occur along the Texas coast (see Hertlein 1951, Pulley 1952). Only four species were identified in my collection, and in only three localities were arcids abundant enough to be noteworthy.

Anadara baughmani Hertlein

This pot-bellied arcid was encountered in 31–37 fathoms at 24° 10′ N. Only a few shells were seen.

Arca transversa Say

Several worn valves were taken in 17 to 20 fathoms a few miles north of Sebree Bank during November, 1950. Small arcid shells, thought to belong to this species, were abundantly attached to empty pen shells, *Atrina serrata*, in 16½ fathoms near Sebree. This little arcid is one of the most abundant mollusks in the shell drift along the Texas coast (Pulley, 1952).

Arca campechiensis Gmelin

Two live specimens of this species were taken in a trynet in 6½ fathoms about 20 miles west of the Sabine jetties. Old rotten arcid shells belonging in part to this species were particularly abundant along the edge of Sabine Bank in 6½ fathoms. Old arcid

shells identified in the field as belonging to this species were noted as abundant in 15½ fathoms southeast of Freeport, Texas.

Noetia ponderosa Say

A few isolated valves of this species were seen along the edge of Sabine Bank among a litter of dead shells.

Anisomyaria

Mytilidae

No live mussels were taken in trawls in the Gulf. One worn valve of *Brachidontes recurvus* Rafinesque was taken in three fathoms off Sabine, Texas. This is a common bay species.

Pteridae

Pteria colymbus Bolton

One live specimen of the wing shell was taken in 17 fathoms off Padre Island. Wing shells are often found attached to the octocoral, *Eugorgia virgularia,* along the jetties at Port Aransas and Port Isabel.

Pinnidae

Atrina serrata Sowerby

Pen shells are sometimes called "angel wings" by Texas fishermen. No live shells were taken but around Sebree Bank in 16½ fathoms about 50 pen shells were taken in a 15-minute trynet haul. These empty shells were all heavily encrusted with an impressive epifauna of bryozoans, small arcid pelecypods, hydroids, serpulid worms and other organisms. Ten was the maximum number seen in the big net, which is, perhaps, an index to the efficiency of the "jumper chain" in eliminating shell. Fishermen have reported capturing as much as a ton of these shells in a single drag near Port Isabel. Only one other specimen, a worn shell, was taken in 7 fathoms off Sabine Bank.

Pectinidae

Pecten gibbus Linné

A few isolated valves, tentatively identified as this species, were taken in 11 fathoms east of Freeport, Texas. Pectens are commonly found in turtle grass, *Thalassia,* in Aransas and Redfish bays. The valves taken offshore were not fresh and may possibly be a subspecies of the common bay pecten (see Pulley, 1952).

Pecten papyraceus Gabb

This thin-shelled pecten is not uncommon in the 30 to 40 fathom zone offshore. Most of the records for the big net are in depths of 31 to 45 fathoms on the 24–10 grounds.

The maximum catch was about six shells in the big net and nearly as many in the trynet. One valve was recovered from 24 fathoms off Corpus Christi Pass. This species was also taken in 17 fathoms southeast of Freeport, Texas, on May 12, 1951, where six specimens were obtained in a single 15-minute trynet haul. Twenty-three paper shelled pectens were taken during 27 hours of trawling in 25–26 fathoms off Mustang Island on February 14–16, 1954.

Ostreidae

Ostrea equestris Say

The distribution of this little flat oyster is partly dependent on attachment surfaces, which are indeed rare on mud bottom. Large specimens were found attached to an old tire dredged in 15 fathoms off Padre Island. It was occasionally found attached to large shells containing hermit crabs; particularly noted was one attached to a *Tonna* shell off Obregon. It was not uncommon on the shell bottom east of Freeport, where it was observed on many shells, including an empty valve of *Chione clenchi.* I have also found them attached to the legs of the decorator crab, *Stenocionops furcata,* and to the spider crab, *Libinia.* Flat oysters are very common on the Campeche Bank.

Eulamellibranchiata

Chamidae

Echinochama arcinella Linné

Live shells are not uncommon on the shell banks in the area of 11–16 fathoms east and southeast of Freeport, Texas. No specimens were taken while trawling on the brown shrimp grounds. The number of shells observed at Big Shell on Padre Island would indicate a large population offshore, landward of the area trawled during this investigation.

Cardiidae

Dinocardium robustum Solander

This large cockle is prized by tourists and is abundant and conspicuous on Texas beaches. A single live specimen was taken in three to six fathoms off Greens Bayou. Six old, encrusted valves were taken in 6½ fathoms about 20 miles west of Sabine, Texas. Apparently it grows in shallow water near shore.

Laevicardium laevigatum Linné

The eggshell cockle was never abundant but it was taken most often in depths of 30 to 40 fathoms on the 24–10 grounds. The writer saw cockles at other localities in the northern Gulf, but never more than two or three specimens in the trynet or large net. A specimen was taken in 12 to 13 fathoms off Wine Island Pass and it represents the shallowest depth of capture.

Veneridae

Chione cancellata Linné

A few old valves were taken in a trynet in 2–7 fathoms off Sabine, Texas.

Chione clenchi Pulley

This little chione is sympatric with *Chione latiliratá* Conrad at least in the Port Isabel area. All of my shells that were identified proved to be *Chione clenchi;* however, two species were not expected during the field work. Only two specimens were listed in the fishing log and this indicates only the exceptional conditions that would be necessary for the capture of this small clam in a large mesh net. This species was taken in all areas of trawling inside the 20 fathom curve. It was noted as abundant off Freeport in 11 to 16 fathoms. A few dead shells were taken in 6½ fathoms off Sabine. Only *Pitar cordata* and *Macoma tageliformis,* among the pelecypods, were more abundant in trynet catches.

Pitar texasiana Dall

This species was not taken on the brown shrimp grounds, but it was not uncommon on the white shrimp grounds. One hinged shell was taken off Pass Cavallo in 11 fathoms during December, 1950. Old shells of this species were common along the edge of Sabine Bank.

Pitar cordata Schwengel

This species was the most common pelecypod on the brown shrimp grounds. It appeared with almost monotonous regularity in the trynet so that it, along with the small starfish, *Astropecten antillensis,* and the goby, *Bollmannia communis,* were considered trademarks of the brown shrimp grounds. The small numbers shown in the anaylses of the large net hauls are indicative of the inefficiency of otter trawls as clam dredges. The lack of captures in the 30 to 40 fathom zone on the 24–10 ground seems to indicate that *Pecten papyraceus* was the most abundant pelecypod in that depth. However, this is not necessarily true as the trynet was used very little in that area.

One fisherman was of the opinion that this clam was much more abundant in soft mud near snapper banks. I was unable to confirm this statement.

Venus campechiensis Gmelin

Hard shell clams were not taken on the brown shrimp grounds. Old clams, possibly Pleistocene in age, are abundant enough to cover wide areas between the beach and the foredunes on southern Padre Island. Fresh and slightly worn shells are encountered on the Mexican coast a few miles below the Rio Grande. The writer has found live shells on the *Halodule* and *Thalassia* flats in Aransas and Corpus Christi Bay. A few worn shells were encountered off Sabine, Texas, in 6½ fathoms. One fisherman stated that an extensive bed of this clam occurred off Galveston. I was unable to confirm this statement.

Tellinidae

Macoma tageliformis Dall

This was the second most abundant bivalve on the brown shrimp grounds. Most of the records of this fragile clam consist of single valves; and occasional hinged shell was taken. Only one live clam was observed. It was captured in 24 fathoms off Padre Island. Dead shells were taken in all areas from Sabine to Obregon, Mexico.

Mactridae

Spisula solidissima similis Say

Dead shells were not uncommon in trynet drags from three to six fathoms off Sabine, Texas.

Pholadidae

Barnea costata Linné

One specimen was taken in a trynet in 6½ fathoms off Sabine, Texas.

Gastropoda

Only the larger gastropods were recorded. However, very few small gastropods were seen, as the gear was not suitable for their capture. No particular search was made for them in globs of mud and other debris that were occasionally dumped on deck from the trynet.

Mesogastropoda

Architectonicidae

Architectonica granulata Lamarck

Only two specimens of the sundial snail were found in the trawl catches. One was taken between 21 to 30 fathoms on the 24–10 grounds and the other was taken in 11 fathoms off Freeport, Texas.

Calyptraeidae

Crucibulum sp.

A cup and saucer limpet was found attached to a *Polystria albida*, captured in 32–33 fathoms on the 24–10 grounds.

Crepidulidae

Crepidula fornicata Linné

A few specimens were collected in 3–6 fathoms off Sabine, Texas.

Crepidula plana Say

No particular search was made for this little snail, and it was not always recorded. It was common in 3–6 fathoms off Sabine, Texas. It was often noted attached to shells

that contained hermit crabs. There is a specimen in the collection from 17 to 20 fathoms, a few miles north of Sebree Bank.

Strombidae

Strombus alatus Gmelin

Large populations of this snail have not been previously reported in Texas waters. Pulley (1952) mentions living specimens from Port Isabel. Old shells with hermit crabs were taken off Sabine Bank and it is apparently common offshore. Other dead shells were taken in 12 to 13 fathoms off Wine Island Pass in Louisiana. Fifty specimens of the fighting conch were taken during a half hour trynet drag in 11 fathoms off Freeport, Texas. Most of these snails were alive. No specimens were taken deeper than 17 fathoms off Freeport, and this shallow water distribution agrees well with the limited investigations made off Campeche. On the Campeche Bank this species is found most abundant around 10 fathoms.

Naticidae

Polynices duplicata Say

The moon snail is a shallow water snail and is undoubtedly more abundant landward of the area trawled. Several specimens were taken in three to six fathoms during October off Matagorda Peninsula. It was found at the same depth off Sabine in June, but very few specimens were taken.

Cassididae

Phalium granulatum Born

The scotch bonnet is a favorite of tourists along the Texas coast. Although live snails are commonly uncovered by very low tides, it seems to be much more abundant after strong southeasters. It was taken in all areas trawled from Grand Isle, Louisiana to Obregon, Mexico, except Sabine. It was recorded in 21 out of 164 drags with the big net, and it was taken more often in the trynet. It was taken as deep as 31 to 37 fathoms on the 24–10 grounds.

Sconsia striata Gray

The range of this distinctive snail overlaps that of the common scotch bonnet. One specimen was taken in depths as shallow as 14 fathoms during July. It was more commonly encountered in depths greater than 20 fathoms.

Cymatiidae

Cymatium sp.

One empty shell of this genus was taken in 32–40 fathoms off 24° 10′ N.

Distorsio clathrata Lamarck

Thirty-three specimens were recorded in the fishing log, and it appeared about as often in the trynet. Eleven specimens were taken in two drags in 24 fathoms east northeast of Brazos Santiago. The bottom in this area contained large numbers of sand dollars, *Clypeaster ravenelli,* and these blocked the webbing; therefore, the net retained more mollusks. *Pitar,* on which *Distorsio* may feed, was also more abundant in these hauls. *Distorsio* has a general distribution in the western Gulf; it was taken off Louisiana and off Obregon as well as off the Texas coast. Only two small specimens were taken inside 15 fathoms. These occurred at 12 to 13 fathoms off Wine Island Pass in Louisiana.

Tonnidae

Tonna galea Linné

Cask shells were found in 18 drags off Texas, Tamaulipas and Obregon, Mexico. A maximum of five large shells were taken in a single drag off Obregon. Bathymetrically, it was taken in depths of 15 to 35 fathoms.

Oocorys sp.

Two small specimens of this genus were found in depths of 17 to 20 fathoms a few miles north of Sebree Bank.

Eudolium crosseanum Monterosato

One specimen of this snail was taken in 32–34 fathoms off 24° 10′ N.

Stenoglossa

Muricidae

Murex fulvescens Sowerby

Prickly conchs are the bane of shrimp trawlers in certain areas. There are reported to be large populations of this conch off the coast between Sabine and Freeport and another large population around Port Isabel. The writer did not investigate any of the areas where the prickly conch is said to abound. It was recorded in 8 different drags made in depths of 6½ to 24 fathoms. One shell with a large hermit crab was taken in 32 to 34 fathoms off 24° 10′ N.

Murex pomum Gmelin

Only dead shells have been found on the Texas coast (Pulley, 1952). The writer obtained a single dead shell in 15½ fathoms off Freeport. There is a possibility that a large population of this species will be found on the hard shell bottom off Freeport. This is a common snail in the 10 fathom zone off the town of Campeche, Mexico.

Thaisidae

Thais haemostoma Linné

Two subspecies of the common oyster drill have been reported from the Texas coast (Clench, 1927). The large nodulose form was found in some numbers in three to six fathoms off Sabine, Texas.

Buccinidae

Cantharus sp.

A single specimen of this genus was found in 17 to 20 fathoms about 30 miles north of Port Isabel.

Neptuneidae

Busycon perversum Linné and *Busycon contrarium* Conrad

The taxonomy of the large conchs of the genus *Busycon* is in need of clarification. During this investigation all large left-handed conchs of the genus *Busycon* were listed as *perversum*. Pulley (1952) reported only *Busycon perversum* from the Texas coast. However, Abbott (1954) found that *Busycon contrarium* was the common species in the Gulf, and he reported *B. perversum* as a rare species from 4–10 fathoms off the west coast of Florida. I have seen shells of both species as described by Abbott on the Gulf beach, but only *B. contrarium* is represented in the small collection saved from the brown shrimp grounds. Forty-three conchs collected in 25–26 fathoms off Mustang Island during February, 1954 are apparently all referable to *B. contrarium*.

In my collection and in my field notes are references to a large right-handed conch with long, heavy knobs on the whorls. Dr. Harald Rehder has identified one of these conchs from Obregon as a reversed example of *Busycon contrarium*. Three specimens were taken in 30–37 fathoms off 24° 10′ N., one specimen was taken in 17 fathoms off Freeport, Texas, and eight others were taken in 18–20 fathoms off Obregon. Apparently in some areas of the Gulf nearly all *B. contrarium* are right-handed, if, indeed, they should be referred to that species.

The left-handed conch was the commonest snail on the brown shrimp grounds. In part this is explained by its large size and surface dwelling habits, which make it particularly vulnerable to the trawl. Left-handed conchs were taken in all areas trawled, but they appeared to be less common in Louisiana and on the Obregon grounds. They were taken at depths of 37 fathoms off the Mexican coast, which except for one drag, was the maximum depth investigated. This species is also common along shore and in high salinity parts of the lower bays. While only small specimens less than three inches in length were found in three to six fathoms off Sabine, very large specimens are found near Mustang Island beach. At one time they must have been more abundant than now as large numbers of shells appear in Indian kitchen-middens on Shamrock Island. Fishermen say that they fluctuate widely in abundance in Port Aransas area, and in some years they are common.

Busycon pyrum Dillwyn

Pear conchs had an almost identical distribution with *B. contrarium*, but they were slightly less abundant. This difference in abundance perhaps could be explained by differential selectivity of the gear for the species. Small specimens approimately three inches in length were caught with *B. contrarium* off Sabine, Texas.

One drag in 23½ fathoms off Corpus Christi Pass was lost because of torn webbing, possibly due to the number of *B. contrarium* and *pyrum* in the net.

Busycon coarctatum Sowerby

This is the most abundant species of *Busycon* in six to ten fathoms off Campeche, Mexico. A single fresh specimen was taken off Obregon. Possibly it had been thrown overboard by a Campeche fisherman. This species was though to be extinct (Johnson, 1934) until the recent discovery of large numbers off Campeche.

Fasciolaria distans Lamarck

Pulley (1952) reported this species living in 15 to 20 fathoms of water along the Texas coast. I took one live specimen in 12 to 13 fathoms off Wine Island Pass in Louisiana. Two others were found in 15½ fathoms off Obregon, Mexico. Several dead shells were trawled in 3 to 6 fathoms off Sabine, Texas. I found many banded tulip shells in 8 to 10 fathoms off Campeche, Mexico.

Fasciolaria gigantea Kiener

Five specimens of the giant conch were caught in the trawl. All specimens were small (less than 7 inches in length). Except for the hermit crabs the shells were empty. However, they all appeared to be fresh. These conchs were caught in depths of 12 to 18 fathoms. One specimen was taken in 15 fathoms southeast of Freeport; the rest of the specimens were taken off the southern half of Padre Island. This species is abundant on Campeche Bank.

Fusinus couei Petit

A single sponge-covered shell was caught on the Obregon ground. As sponge-covered shells are typical of conditions noted on Campeche Bank, but not at Obregon, it seemed highly probably that this specimen was thrown overboard by a Campeche trawler.

Olividae

Oliva sayana Ravenel

This is a shallow water species. Live olive snails were taken off Greens Bayou in three to six fathoms, and a dead shell was found in 11 fathoms east of Freeport, Texas.

Conidae

Conus austini Rehder

This drab colored cone shell was found in the greatest number in depths 30 to 40 fathoms on the 24–10 ground. One small specimen was caught in a drag in 19 fathoms off Obregon. It was also found off Greens Bayou in 18 fathoms.

Turridae

Polystria albida Dall

This species was most abundant on the outer edge of the present shrimp fishery. It was most common in depths of 31 to 37 fathoms on the 24–10 grounds. Several specimens were caught in 16 to 20 fathoms off Obregon. The sole remaining locality that this species was taken was in the region of Matagorda Island in 18 to 22 fathoms.

Opisthobranchiata

None of the nudibranchs captured have been identified. Nudibranchs were inconspicuous and rare. Four specimens representing three species were found in the large trawl. Three additional specimens representing two species were noted in the trynet. One large tectibranch, probably *Aplysia floridensis* Pilsbury, was taken in 19 fathoms off Obregon, Mexico.

Cephalopoda

Decapoda

Loliginidae

Loligo pealei LeSueur

Nearly 4,800 squid were taken in 43 drags or approximately 110 squid per drag. However, squid were recorded in only 57 of 145 drags completed. An expected peculiarity of the squid is shown by my data. Night time catches of squid were nearly always small and the abundance increased greatly in the last drag which was completed at sunrise or slightly after sunrise. Whether these increased catches would have continued through the day cannot be definitely determined from my data. Very few daytime drags were made. Those made in May indicated a continuing abundance throughout the day until sunset. One complicating factor is that the sea was quite rough and catches of brown shrimp were also continuing undiminished during the daytime.

Few conclusions can be drawn as to seasonal abundance because of the absence of definite monthly stations and standardized gear. However, the greatest abundance was encountered in July in 14 to 18 fathoms.

On May 12, 1951 two large squid were caught in a trynet. The depth was 17 fathoms and the locality was southeast of Freeport, Texas. The mantle lengths of these squid were around 29 cm., nearly a fourth larger than the rest of the squid taken. These large squid are called "flying squid" by the fishermen and the writer was told that they were common off Aransas Pass in 25 to 30 fathoms during March and April, 1951.

Lolliguncula brevis Blainville

Gunter (1950) found this little squid to be the most common cephalopod in the inshore waters of the Texas coast. The writer caught 2,600 of these squid in 21 drags in the western Gulf. It was very rare in water deeper than 15 fathoms except during January, when nearly 400 were taken in 20 to 21 fathoms off Corpus Christi Pass in a single drag. Gunter found this little squid in the lower bays except in the coldest months of the year, when the whole population moved out to sea. The two observations indicate an inshore and offshore movement with the seasons. The only other large

catches of this species were made while trawling for white shrimp off Sabine, Texas, and Grand Isle, Louisiana.

Sepiolidae

Rossia tenera (Verrill)

A single specimen was captured in 23 fathoms of water off Corpus Christi Pass. This species is too small to be retained in large mesh nets, except under unusual conditions.

Octopoda

Octopodidae

Octopus vulgaris Lamarck

The common octopus is rare along the Texas coast as has been pointed out by Gunter (1950). Only a single specimen was taken in 31 to 37 fathoms off 24° 10′ N. It was probably using a large cask shell for a refuge, as an empty one was found in the net. This species is known to be very common off Campeche in 10 fathoms, where the writer found them hiding in old *Fasciolaria gigantea* shells. There are fishermen's reports that this species is not uncommon on the "shell piles" in 11 to 17 fathoms off Freeport, Texas.

Octopus joubini Robson

Three small specimens of Joubin's octopus were captured. Two were found among a pile of empty *Atrina* shells, which comprised most of a trynet haul in 16½ fathoms a few miles north of Sebree Bank. One other specimen was taken in a trynet in 17 fathoms southeast of Freeport, Texas.

Arthropoda

Crustacea

Stomatopoda

Three species of stomatopoda are known to live on the Texas coast. *Lysiosquilla scabricauda* and *Squilla empusa* were taken on the offshore grounds. The distribution of *Lysiosquilla excavitrix* Brooks is not well known, but it has been taken in a minnow seine near the south jetty at Port Aransas.

Squilla empusa Say

Usually this odd little crustacean is pointed out to visitors by the shrimp fishermen as one of the strange animals that come up in the trawl. Many different names are given to it by the fishermen. Gunter (1950) found that mantis shrimp preferred oceanic salinities and was not found in the bays except in the portions of the bay with high salinites. Except for shrimp of the genus *Penaeus* and the Gulf crab, *Callinectes danae*, it is the most abundant crustacean in the offshore trawl fishery. Nearly 28,000 specimens were counted in the large trawl. Moreover, it was recorded in over 95 per

cent of the drags completed. In the area investigated, no locality was found where the mantis shrimp did not occur. While it is difficult to interpret the data because much of it was made at different times of the year and with slightly different gear, the following conclusions appear warranted:

1. Mantis shrimp were found in depths between 3 and 45 fathoms, the extent of the area investigated.

2. It was recorded most abundantly in 19 to 23 fathoms off Grand Isle, Louisiana, where as many as 4,600 were taken in a single drag.

3. The results of limited trawling in 30 to 40 fathoms support the conclusion that the mantis shrimp is most common inside 30 fathoms.

Lysiosquilla scabricauda Lamarck

Two specimens of this large stomatopod were taken in 20 to 22 fathoms off the southern half of Padre Island, and one specimen was taken in 15–16 fathoms off Obregon, Mexico. On the Campeche Bank this species is common but it appears to be rare on the Texas coast. This may be due to a preference for shell bottom. Furthermore, *L. scabricauda* appears to be most common inside 12 fathoms; several dozen specimens were washed ashore on the Gulf beach near the south pier at Port Aransas after a windstorm during October, 1953.

Decapoda

Penaeidae

Penaeus setiferus (Linnaeus)

The decline in the white shrimp production has been previously discussed. Table 1 shows the decline in the landings of white shrimp in Texas and the total decline in shrimp production in Louisiana. Unfortunately, satisfactory statistics are not available on the relative positions of *P. setiferus* and *P. aztecus* in the Louisiana landings before 1951, when Denham (1952) found that white shrimp comprised 85 per cent of the Louisiana landings. However, it is known generally that brown shrimp were not caught in any abundance before this time in Louisiana (*cf.* Weymouth, Lindner and Anderson, 1933). Reasons for the decline of the white shrimp are not within the provenance of this paper and are not discussed.

Gunter (1943) has summarized the shrimp fishery of Texas. The conditions which he found in the Texas fishery are essentially the same as those described by Johnson and Lindner (1934) for the entire fishery. The white shrimp fishery in the northern Gulf is a bimodal one, that is, there is a spring peak in production during the months of April, May and June and a larger fall mode during the months of September, October and November. Collier (1938) reported that the spring fishery was offshore, while the fall fishery was chiefly confined to the bays.

The Fish and Wildlife Service found by tagging that there was a southward movement of adult white shrimp from the Carolinas and Georgia to Florida during the winter and an offshore migration in Louisiana. Gunter (1943) reported that no particular winter concentrations of white shrimp were known on the Texas coast, nor has one been found since that date. Lindner (1943) postulated a southern migration of white shrimp along the Texas coast. The results of the tagging experiments by Anderson

along the northeast coast of Mexico have not been published, but according to news releases in the Atlantic Fishermen, white shrimp tagged in Mexico were retaken off Aransas Pass, Texas. However, Anderson tagged shrimp during 1947 when a record breaking "strike" of shrimp appeared in the Port Isabel-Tamaulipas area; therefore,

TABLE 1

Shrimp Production of *P. aztecus* and *P. setiferus* in Louisiana and Texas*

Year	Louisiana (Thousands of Pounds)†	Texas *P. setiferus* (Thousands of Pounds)	Texas *P. aztecus* (Thousands of Pounds)
1940	83,410	14,799	.....
1941	116,414	19,319	.....
1942	102,726	21,785	.....
1943	92,703	22,916	.....
1944	114,419	18,615	.....
1945	104,160	15,722	.....
1946	97,646	21,521	.....
1947	66,780	21,791	2,420
1948	79,087	14,900	7,516
1949	78,960	12,010	21,658
1950	74,737	12,651	28,352
1951	84,000	6,517	46,193
1952	not available	5,260	48,495

* Catch records are from the Louisiana Department of Wildlife and Fisheries. The production in Texas is from statistics of the Fish and Wildlife Service, where available, and the Texas Game and Fish Commission, with a correction of one-fifth added to the latter. The estimates of Whites and Browns are from Hildebrand and Gunter (1953).

† Includes both *P. aztecus* and *P. setiferus*.

conditions may have been atypical. Indeed, a northward spring migration is plausible, and it is supported by the fact that usually the first large spring "run" of white shrimp appears on the Texas coast in the neighborhood of Sebree Bank in 14–16 fathoms of water. However, there is no orderly progression of the fishery up the Texas coast and the best explanation may be a scattering of the shrimp in offshore waters during the winter and reconcentration in the shallow coastal waters during the spring.

The first half of 1950 was characterized by the large spring run of white shrimp in the Galveston area. The production at Galveston was of record or near record proportions for the month of May. Approximately 4,000,000 pounds of white shrimp were landed in Texas ports during May. However, when the writer started his investigations the commercial fishermen were still waiting for the fall run of white shrimp to materialize.

I visited the white shrimp grounds during the months of October, December and June. The catches were never large, and the concentrations of white shrimp were found only after intensive search by the fishermen. During June, it was necessary to prospect for bottom relatively free of croakers, *Micropogon undulatus*, as well as to search for white shrimp. White shrimp were, indeed, rare on the brown shrimp grounds, and only a few dozen specimens were taken in depths greater than 14 fathoms. The maximum depth that I found white shrimp along the Texas coast was 21 to 23 fathoms. White shrimp were taken only during daytime drags on the brown shrimp grounds.

A total of 48 hours was spent trawling for white shrimp. The rate of capture was 121.7 pounds per hour and 3.9 pounds per acre. The greatest catches were recorded during October, when a "run" of shrimp was encountered off Pass Cavallo. The rate of capture was 182.9 pounds per hour and 5.4 pounds per acre. Many small shrimp were discarded during October, but nearly all shrimp caught during December and

TABLE 2

Commercial Landings of White Shrimp, *Penaeus setiferus*, by Trawlers Used in This Investigation

Month	Weight in pounds (Heads on)	Number of Drags	Total Hours of Trawling	Average per Hour Trawled (in Pounds)	Total Acres Trawled	Average per Acre	Normal Trawling Average per Hour	Normal Trawling Average per Acre
October "SJ"	3,155	10	17 h. 40 m.	179.3	590	5.3	182.9	5.4
November "RB"	very few*	----	----------	------	------	----	------	----
December "GG"	140	1	2 h. 45 m.	50.9	90	1.6	50.9	1.6
May "CGH"	very few*	----	----------	------	------	----	------	----
June "FL"	1,300	8	12 h. 20 m.	105.7	330	3.9	105.7	3.9
June "A"	225	2	2 h. 50 m.	79.5	65	3.5	79.5	3.5
June "MM"	990	4	12 h. 35 m.	78.7	420	2.4	78.7	2.4
Total	5,810	25	48 h. 10 m.	120.6	1,495	3.9	121.7	3.9

* See fishing log.

June were larger than 36 count. The smallest catches were recorded in December, when the rate was 50.9 pounds per hour and 1.6 pounds per acre.

Penaeus aztecus Ives

As the production of white shrimp has declined, the catch of brown shrimp has increased. Table 1 shows the increase in the brown shrimp fishery in Texas. Since brown shrimp have been fished in significant quantities for only five years, few data on production are yet available. The following table is based on data generously supplied by Mrs. Lena Cole, the Fishery Market News representative in Aransas Pass, Texas. As only two years of records are available, the dates from July 1, 1951 to July 1, 1952 were chosen. These months were picked for the following reasons: 1. The production of shrimp was high on the Texas coast and no appreciable landings were made in Aransas Pass except from the Texas and 24–10 grounds. 2. The production of white shrimp was light. Consequently, there was only a partial diversion of the fleet to the

TABLE 3

Landings of Shrimp at Aransas Pass, Texas from July 1, 1951 to July 1, 1952

Month	White Shrimp *Penaeus setiferus* (Linnaeus) Pounds	Brown Shrimp *Penaeus aztecus* Ives Pounds	Percentage of 15/20's in Monthly Catch
July, 1951	15,000	511,000	19
Aug. 1951	1,500	1,274,000	8
Sept. 1951	8,900	1,562,000	17
Oct. 1951	44,000	1,258,000	31
Nov. 1951	608,000	695,000	43
Dec. 1951	64,000	1,350,000	14
Jan. 1952	0	695,000	18
Feb. 1952	750	440,000	60
Mar. 1952	15,000	412,000	47
April 1952	17,000	337,000	64
May 1952	301,000	359,000	29
June 1952	174,000	154,000	27

white shrimp fishery, notably during November. 3. These dates appear to coincide with the yearly cycle of the brown shrimp fishery in Texas waters, *i.e.*, a large group of young shrimp appear in the offshore fishery for the first time during July.

The use of the period included in Table 3 might be criticized on the basis that the "run" of shrimp off the Texas coast was exceptionally heavy during the last half of 1951.

Very little is known of the natural history of *Penaeus aztecus*. Pearson (1939) says that the planktonic young of *Penaeus brasiliensis*, for the most part probably *P. aztecus*, are taken throughout the year, but in reduced numbers during the winter. Gunter (1950) found that the young were present in the bays throughout the year. He further showed that they were most common in the spring to early summer and in the fall and in lessened abundance during the winter and midsummer.

The production of brown shrimp for Aransas Pass does not show the bimodal curve which is typical of the white shrimp on the Texas coast. Offshore production of brown shrimp reaches its lowest level during the spring and early summer months. This is true not only for the total catch, but also for the catch per boat. Fishermen are ready to admit by the middle of March that most of the brown shrimp are gone until next July or August. Production increases rapidly when schools of small brown shrimp, 26–41 count, are located offshore usually in July but sometimes as late as August. This rise in catch corresponds to the period of midsummer decline in the bays found by Gunter (*op. cit.*, table 6) and doubtless results from egress of small shrimp from the bays. High production is then maintained and increased by the rapid influx of boats that always occurs when a "strike" of shrimp is reported anywhere in the Gulf. Moreover, the 24–10 beds are noted as a winter fishing area and many boats are based in Port Isabel during the winter. Data are not available to evaluate the three factors of growth, immigration of small shrimp into the fishery, and the emigration of the larger shrimp beyond the area fished. Fishermen fish the larger shrimp when they are available, for economic reasons. Bay fishermen in recent years have caught large quantities of brown shrimp, 42/65 count, in the bays and near the Gulf beaches during late May and June.

TABLE 4a

Commercial Landings of Brown Shrimp, *P. aztecus*, by Trawlers Used in This Investigation*

Month	Number of Drags	Weight in Pounds (Heads on)	Total Hours of Trawling	Average per Hour (In Pounds)	Total Acres Trawled	Average per Acre (Pounds)
May	21	5,855	105 hrs. 10 m.	55.6	2,840	2.1
October	9	3,330	31 hrs.	107.4	1,040	3.2
November	11	5,635	36 hrs. 25 m.	154.8	1,220	4.6
December	11	5,175	44 hrs. 45 m.	115.6	1,500	3.5
December	4	1,400	16 hrs. 20 m.	85.9	545	2.6
January	6	2,590	25 hrs. 25 m.	101.9	965	2.7
January	4	825	16 hrs. 15 m.	50.8	545	1.5
March	14	3,545	62 hrs. 15 m.	56.9	2,085	1.7
March	2	975	12 hrs.	81.3	400	2.4
April	2	160	11 hrs. 10 m.	14.3	330	0.5
May	21	5,855	105 hrs. 10 m.	55.6	2,840	2.1
June	2	735	7 hrs. 10 m.	102.6	240	3.1
July	21	9,620	65 hrs. 15 m.	147.4	1,925	5.0
July–August	32	18,825	80 hrs.	235.3	2,680	7.0
Total	139	58,670	513 hrs. 10 m.	114	16,315	3.6

TABLE 4a—*Continued*

Month	Efficiency of Trawl Impaired		Normal Trawling	
	Total Hours	Total Acres	Average per Hour	Average per Acre
October	0	0	107.4	3.2
November	17 hrs. 20 m.	580	210.9	6.3
December	0	0	115.6	3.5
December	0	0	85.9	2.6
January	4 hrs.	150	118.0	3.1
January	3 hrs. 55 m.	130	67.1	2.0
March	12 hrs. 45 m.	430	63.3	1.9
March	0	0	81.3	2.4
April	7 hrs.	205	34.8	1.2
May	30 hrs. 40 m.	830	69.1	2.5
June	0	0	102.6	3.1
July	2 hrs.	60	148.9	5.1
July–August	5 hrs. 45 m.	195	241.8	7.3
Total	83 hrs. 35 m.	2,440	128.0	4.0

* Total hours of trawling refers to the total time the net was on the bottom. Normal trawling refers to drags completed without damage to the net.

The writer's investigations were conducted on large trawlers. No special pattern was followed in visiting the shrimp beds in the western Gulf. Actually the district that the writer worked was dictated by the location of the large trawlers. The following summary is based on the monthly catches of brown shrimp.

From October 20, 1950 to September 1, 1951, I made one or more trips per month, except during February, to the brown shrimp grounds in the western Gulf of Mexico. The greatest catches were made during August on the Obregon Grounds; shrimp were caught at the rate of 242 pounds per hour and 7.3 pounds per acre. The lowest catches were made during April when shrimp were caught at the rate of 34 pounds per hour and 1.1 pounds per acre.

TABLE 4b

Production of *Penaeus aztecus* in 12–13 Fathoms Off Wine Island Pass, Louisana

Month	Number of Drags	Weight in Pounds (Heads on)	Total Hours of Trawling	Average per Hour (In Pounds)	Total Acres Trawled	Average per Acre Pounds
June	4	1,560	12 hrs. 35 m.	44.5	850	0.7

In summarizing the catch data for all boats, certain things should be recalled. One is that the gear was not standard, the nets were rigged differently, and some nets were larger than others. Although all trawling was done on boats operated by very capable fishermen, some captains prospected more for shrimp before they put the large net overboard. This would tend to decrease the hours trawled at sea, but it should and often does increase the catch per drag.

If all catches of brown shrimp caught on the white shrimp grounds and off Wine Island Pass, Louisiana, are excluded, the writer trawled nearly 513 hours on the brown shrimp grounds for a catch of 58,670 pounds of whole shrimp (commercially marketed). However, nearly 84 hours of trawling time were entirely or partly lost because of mishaps to the gear. The catch averaged 128 pounds per hour of normal trawling and 4 pounds per acre. Approximately 1,360,000 shrimp were caught.

Natural History

Few observations were recorded on the natural history of *Penaeus aztecus* besides the data collected from the commercial catches, and the animals associated with the brown shrimp.

Although samples were collected and deposited in the Institute of Marine Science collection, no information was recorded on sexual maturity.

Burkenroad (1939) has called attention to the disparity in size between the adult male and female *P. aztecus*. This size disparity makes the grading of the catches of *P. aztecus* necessary as the catches are of course always mixed.

Burkenroad has discussed a difference in sex ratio between shrimp caught inshore and those from deeper water. It may be well to point out that most of Burkenroad's samples were collected during the day, and from what we know of the movements of the brown shrimp, these samples may be atypical of the population. The large females may be simply more available to fishing gear during the day than at night. I have no data specifically bearing on this problem. Repeatedly it was observed that large brown shrimp were rare in trynet catches. The following sex ratios were obtained by counting the entire trynet catch:

January 4, 1951, Depth 17 fathoms, off Corpus Christi Pass 24 males/5 females
May 14, 1951, 21 fathoms, off Padre Island, 45 males/67 females

In the large net the following ratios were obtained:

March 10, 1951, 32–34 fathoms, off northeast Mexico, 45 males/50 females
May 14, 1951, 21 fathoms, off Padre Island, 45 males/67 females
July 11, 1951, 18 fathoms, off Padre Island, 91 males/85 females
August 5, 1951, 15½ fathoms, off Obregon, Mexico, 62 males/34 females.

These data are too few to show convincingly a different sex ratio at different depths, but they do demonstrate a difference in selectivity of the gear. The following interpretation seems best to explain the phenomenon. Large females are able to avoid the 10 to 16 foot trynets by rapid movement, while in the large nets with 3 inch mesh instead of the 2 inch mesh of the trynet, the smaller males may escape through meshes which retain all the large females.

Penaeus duorarum Burkenroad

Penaeus duorarum was first reported from Texas waters by Gunter (1950). Although he did not separate the two species in the field, he states, "The percentage of *P. duorarum* in the total is unknown, but it seemed to be small and was possibly less than one per cent." During March, 1953, bait dealers in Rockport were selling mostly *P. duorarum* as live bait, but no great abundance of this species in the bays was reported.

Penaeus duorarum supports important commercial fisheries off Key West and on the Campeche bank. This species has an ecological preference for shell sand, and its distribution in the northern Gulf may be limited by the absence of large areas of shell sand.

I have found only 11 records of the capture of this species in my data on offshore trawling in the northwest Gulf. It is probable that some specimens were confused with *P. aztecus*, especially in the smaller size groups, but the percentage seemed small.

TABLE 5

Production of *Penaeus duorarum* in the Gulf of Campeche by Area of Landings*

Year	Texas (Thousands of Pounds)	Florida (Thousands of Pounds)
1950	1,500	.....
1951	5,530	7,185
1952	460	23,000

*The Texas landings are from the Fishery Market News Service except the estimate for 1950 which is my own. Florida landings are from the Fish and Wildlife Service. An unknown quantity of brown shrimp, *P. aztecus*, from the Obregon grounds are included in the Florida landings. Statistics of Mexican landings are not available. Trade journals report landings of 15 to 20 millions of pounds of Browns, Whites and Pinks in Mexican ports in the Gulf of Campeche.

This species was slightly more common on the Obregon grounds, but even there it made up an insignificant percentage of the catch.

Two additional specimens of this species were taken in trynet tows in 13 to 14 fathoms east of Freeport, Texas. There are no records of this species for Louisiana west of the Mississippi River. The species is well known in the northeastern Gulf, where Springer (1951) states that it comprises 30 per cent of the grooved shrimp catch at times. Fishermen have reported to the writer that there are areas of hard sand bottom in the northeastern Gulf, where only spotted shrimp are caught. Fishermen have also reported restricted areas along the Texas coast where nothing but pink shrimp are caught, but I have not been able to confirm the existence of any of these grounds.

Springer (1952) has listed this species in his fishing log for the Texas coast during November, 1950. Apparently all his specimens were captured between the shore and ten fathoms off Port Aransas, Texas. During the spring of 1954 small pink shrimp were common in depths of 0–10 fathoms off Padre Island. This condition may prevail every year, but I have no data on this shallow water area for previous years.

Trachypeneus similis Smith

A few specimens from the following localities, Obregon, 24–10 grounds, Padre Island and off Sabine (6½ fathoms) were determined by Burkenroad as *T. similis*. If *T. constrictus* occurred at all, it was not recognized. In shallower water off Port Aransas, Gunter (1950) reported only *T. constrictus*. An important field character for separating the two species according to Burkenroad (1939) is a color difference. Two color patterns were not discerned during my field work.

T. similis was recorded in 127 drags out of 136 completed between November, 1950 and August, 1951. Next to *P. aztecus* this was the most common species of shrimp in the trawl hauls. This species was uncommon in depths of less than 12 fathoms, and it appears to prefer a mud bottom.

T. similis is a small shrimp and undoubtedly large numbers escape through the meshes of the large shrimp trawls. There is no common name for this species, as most fishermen suppose it is the young of one of the other species. The largest female I measured was 130 mm. in total length, but most of the shrimp were much smaller. In the drags that were recorded numerically, 38,800 *T. similis* were counted, 300 on the white shrimp grounds off Sabine, Texas, 28,000 on the Texas grounds, 2,800 on the Obregon grounds, 4,300 on the 24–10 grounds, and 3,400 on the Southwest Pass grounds. No length frequency data were recorded, but small *Trachypeneus* were es-

pecially noted during May 12–16, 1951. Gunter (1950) found the small *T. constrictus* in March. No seasonal abundance trends were detected.

This species has little commercial importance. A few specimens were found mixed with canning shrimp, *P. aztecus* and *P. setiferus*, in the landings at Grand Isle, Louisiana, during June, but it comprised only a very insignificant percentage of the landings.

Xiphopeneus krøyeri (Heller)

Very little information is available in the literature on the natural history of the seabob; even the broad details of its distribution in the Gulf of Mexico are unknown. Burkenroad (1934) states that it is abundant in Louisiana, and he lists no other localities for the Gulf. In Louisiana the seabob is abundant enough to be exploited commercially. Formerly most of the catch was dried for export, and Johnson and Lindner (1934) state that it comprised about 2½ per cent of the commercial landings in Louisiana. Sporadically, the seabob has been exploited in Texas in recent years. The Texas Landings, the monthly statistical digest of Texas fishery, lists a catch of 100,000 pounds for Galveston during April, 1952. However, there is a distinct probability that a part of this catch is *P. aztecus*, as the dealers do not always distinguish the juvenile, *P. aztecus*, from seabobs.

Gunter (1950) concluded that this species was confined to a narrow zone paralleling the beach and only rarely straying deeper than 10 fathoms. He also found that it entered the lower bays during the winter months. Burkenroad (1939) reported six specimens from 16–24 fathoms. The writer obtained no specimens in the western Gulf at depths greater than seven fathoms. This species appears to be more abundant from Freeport to Sabine than elsewhere along the Texas coast; whether this is due to salinity relationships, greater width of the shallow water zone, or other causes is not known.

Seabobs were taken in nine different drags of the large net. Six of these drags were made near Greens Bayou on October 23, 1950. This species is listed as common in only two drags. Although no counts were recorded, it is estimated that no more than 5,000 specimens were captured during October. An estimated 5,000 more were taken in three trawl hauls off Sabine, Texas, during June, 1951.

Sicyonia

These very colorful shrimp are called rock or stone shrimp by the fishermen. This refers to their hard thick exoskeletons and is not based on their habitat. Three species were detected in our catches. One of them, *S. typica*, has not previously been found in the western Gulf. All three specimens are distinctively colored and easily recognized in the field. An attempt was made to determine the ecological separation of *S. brevirostris* and *S. dorsalis* when certain anomalies in distribution of these two shrimp were noted.

Rock shrimp have little commercial importance. Some fishermen save a few for home consumption, and one fisherman retails a few *S. brevirostris* at Port Isabel, Texas. Probably the main reason they are not used commercially is the absence of large exploitable populations. Moreover, the most common species, *S. dorsalis*, is a small shrimp.

Sicyonia brevirostris (Stimpson)

Very few data have accumulated on the distribution of this species as only a few museum specimens were available heretofore. However, *S. brevirostris* has been recorded from South Carolina, Louisiana, Yucatan, Bahama Islands, Straits of Florida and the Pacific coast of Mexico (Burkenroad, 1934, 1939; Lunz, 1945).

This species was ubiquitous on Campeche Bank during February in depths of six to ten fathoms, where the bottom was white shell sand. While numerical data will not be presented here, it was the second most abundant species of shrimp on the Campeche grounds during February, 1951.

Approximately 6,100 specimens of this species were counted in shrimp trawls. It was caught in all areas except off Sabine (less than seven fathoms). An examination of Table 6 will show several peculiarities in the distribution of this species. First, *S.*

TABLE 6a

Catch of *Sicyonia* by Areas

Locality	Number of *Sicyonia dorsalis*	Number of *Sicyonia brevirostris*
Texas Grounds (12–25) fms.)	15,655	443
Southwest Pass Grounds (12–24 fms.)	100	2,507
Sabine (3–6¾ fms.)	1 (small)	
24–10 Grounds (21–45 fms.)	6,805	1,670
Obregon Grounds (13–20 fms.)	1,800	1,600

TABLE 6b

Catch of *Sicyonia* by Depths

Depth (in fathoms)	Number of *Sicyonia dorsalis*	Number of *Sicyonia brevirostris*
6¾	1	0
12–15	535	2,550
15–20	8,875	1,887
20–25	7,905	170
21–31	1,725	50
31–37	5,080	1,620

brevirostris is rare in depths of 15 to 25 fathoms, where *S. dorsalis* predominates. However, on the same type of mud bottom in depths of 31 to 45 fathoms it was relatively more abundant. As previously stated, this species is very abundant in 6 to 10 fathoms off Campeche, and an evidence of inshore abundance in the northern Gulf is indicated by the capture of 2,500 specimens in a single drag off Wine Island Pass in Louisiana. The limited data suggests two areas of abundance separated by a band of *S. dorsalis*. Specimens from inshore and offshore bottoms were determined by Burkenroad to be the same species. While the possibility that *S. brevirostris*, like *P. setiferus*, is more active during the day, and *S. dorsalis* is more active at night is not definitely eliminated, trawling data from Campeche do not support such a conclusion. The third possibility also exists that *S. brevirostris* strays from snapper banks or areas of hard sand and

that the catches on mud bottom represent such strays. Lunz (1945) calls it the coral shrimp and he records it from the coral banks off South Carolina.

Off Obregon, the three species, *S. brevirostris, S. typica,* and *S. dorsalis,* were sometimes taken in the same drag. As 1,600 *S. brevirostris* were taken to 1,800 *S. dorsalis* on the Obregon ground, it would appear that there was little difference in abundance of the two species, except that one-third of the catch of *S. brevirostris* came from a single drag. This drag was made in 19 fathoms, and all three species were captured in it.

Sicyonia dorsalis (Kingsley)

Only *Penaeus aztecus* and *T. similis* were more abundant than this little shrimp in the trawl catches on the brown shrimp ground. Approximately 24,280 shrimp were recorded in 69 drags. It was also recorded in 41 other drags.

This species occurred throughout the depths investigated, but it was most common on muddy bottom in depths of 15 to 25 fathoms. Only two drags were made on Campeche Bank in depths as great as 16 fathoms, and this species was observed but it was not common. It was not recorded in depths shallower than 13 fathoms on the Campeche Bank. The small number taken off Obregon may in part be explained by the gear used. The "jumper chain" appears to reduce the catch of this species.

Smaller specimens occasionally appear inshore on the Texas coast even to the mouths of the bays. One small specimen was taken in 6½ fathoms off Sabine.

Sicyonia typica (Boeck)

All nineteen specimens of this species were taken off Obregon in depths of 17 to 20 fathoms. There are also a few specimens from the Lobos Island grounds in the collection of the Institute of Marine Science. The absence of this species from the shallow water of the Campeche Bank may be explained by its preference for deeper water. This species has been previously recorded from the west coast of Florida, the Cayman Sea and Brazil. According to reports in the Southern Fisherman this species is fished commercially in Golfo de Batabano off the southwest coast of Cuba. Dan Kornegay, a Texas shrimp fisherman, informs me that this species occurs on the Chiltepec shell bank in commercial quantities, but there is no market for the species in the United States.

Solenocera vioscai Burkenroad

Burkenroad (1939) found this species in depths of 20 to 100 fathoms off Louisiana. A relatively small number of specimens were observed, which is to be expected, as most of its known bathymetric distribution is seaward of the depths usually fished for brown shrimp.

While this species was most common in 31 to 37 fathoms on the 24–10 grounds, no numerical records were kept but an estimated 2,000 specimens were captured. Otherwise, a few handfuls of this species were caught per drag in depths of 17 fathoms or greater during May and a total of 21 specimens were seen on the Obregon grounds. An estimated 3,000 specimens were captured during the entire trawling operations.

Crangonidae

Small snapping shrimp were caught in great abundance on the sponge grounds of Campeche Bank, but only a single specimen was seen on the Texas coast. It was found in a trynet haul in 12 fathoms east of Freeport, Texas.

Scyllaridae

Scyllarides aequinoctialis (Lund)

One flat lobster was captured in 17 fathoms of water on July 11, 1951 approximately 20 miles north of Sebree Bank. The specimen was an ovigerous female with a carapace length of 90 mm. Shrimp fishermen rarely see this strange crustacean, and presumably only strays from snapper banks are caught in trawls. A fisherman brought two of these rock lobsters into a Freeport fish house on May 6, 1951.

Porcellanidae

Porcellana sayana (Leach)

This little louse crab was often found in the trawl catches. Usually it had been jarred loose from its association with the large red hermit crab, *P. bahamensis*. Six specimens were found attached to the decorator crab, *S. furcata*. *P. sayana* was found in all depths and all localities investigated.

Paguridae

Hermit crabs are hard to remove from the shell for rapid field identification. Only a few notes were taken on abundance. The common hermit crab on the brown shrimp grounds was a large red species, *Petrochirus bahamensis*. The lack of suitable large snail shells probably limits its abundance on the mud bottoms of the brown shrimp grounds. This hermit crab was very abundant on Campeche Bank.

Another smaller hermit crab was observed at Sabine, and this crab was probably a species of *Pagurus*. It was not common in the trawl catches.

Brachyura

Large crabs were often very abundant in the trawl hauls. No systematic search was made for small xanthid crabs and they were not always recorded. However, small xanthid crabs were rarely captured on the brown shrimp grounds, but they were very abundant among the loggerhead sponges on Campeche Bank. Small spider crabs are too fragile to survive in the large trawls and they are found most often in the trynet.

Majidae

Stenorynchus seticornis (Herbst)

Arrow crabs were not detected in the large trawl catches. One ovigerous female was taken in 17 fathoms south of Freeport, Texas during May. Another specimen was taken in 12–13 fathoms off Wine Island Pass in Louisiana during June.

Podochela sydneyi Rathbun

One specimen was taken in a trynet in 17 fathoms south of Freeport, Texas. Four other specimens were taken in 12 to 13 fathoms off Wine Island Pass, Louisiana. The legs of one specimen were densely covered by a hydroid, and one had a small ascidian, *Styela*, attached to a leg.

Anasimus latus Rathbun

A single ovigerous female of this species was taken in 19 fathoms off Obregon, Mexico.

Stenocionops furcata (Olivier)

A single specimen of the decorator crab, carapace width 73 mm., was captured in 18 fathoms off St. Joseph Island. Apparently this is the first record of this species from the northwestern Gulf. The crab was covered with an impressive epifauna, including bits of algae, hydroids, bryozoans, three large anemones, *Calliactis tricolor*, and three small flat oysters, *Ostrea equestris*.

Stenocionops spinosissima (de Saussure)

Seven specimens of this large spider crab were taken in 31–37 fathoms of water on the 24–10 grounds. The following carapace widths were recorded: male, 122 mm., female, 95 mm. More recent investigations indicate that this species is common off the Texas coast. I took 6 crabs during 12 hours of dragging in 25–26 fathoms off Mustang Island on February 15,1954. One crab, carapace width 72 mm. was ovigerous. Additional specimens were brought into the laboratory from 33–49 fathoms off Mustang Island during April, 1954 by shrimp fishermen. Two of these crabs were ovigerous.

Libinia emarginata (Leach)

Two species of *Libinia* occur in the western Gulf; all specimens captured during this investigation were identified in the field as this species. Thirty-three specimens were captured. This is the most common large spider crab in the area investigated. It was captured in depths of 6 to 24 fathoms, and it was most abundant during July. No specimens were taken in Louisiana or off Obregon. The young of this species often ride in the bell of the scyphozoan, *Stomolophus meleagris*, in the Texas bays. On one occasion the writer observed a spider crab feeding on a juvenile butterfish, *Poronotus triacanthus*, which also seeks refuge in the bell of the scyphozoan.

Two ovigerous females were seen during the first half of July, 1951. I took an ovigerous female, carapace width 75 mm., in 25–26 fathoms of water off Mustang Island on February 15, 1954.

Parthenopidae

Leiolambrus nitidus Rathbun

This species was found only once in the large net. All other specimens were found in the trynet. This crab was taken occasionally in 6–24 fathoms along the Texas coast. Six crabs were taken in trynet drags in 14, 15 and 17 fathoms south of Freeport, Texas.

The greatest number in any trynet drag was four in 17 fathoms south of Freeport, Texas, on May 12, 1951. Ovigerous females were taken during June in six fathoms south of Sabine, Texas, and in 12–13 fathoms off Wine Island Pass, Louisiana.

Most of the crabs of this family are small and fragile. At least one other species was taken twice, but it has not yet been identified.

Portunidae

Portunus spinimanus Latreille

Forty-four specimens of this swimming crab were recorded. Most of these identifications were made in the field, and there is a possibility that a few *P. gibbesi* are included, but the number was certainly small. Carapace widths of specimens in my collection range from 26–79 mm. The writer has taken this species along the jetties at Port Aransas as well as in 37 fathoms on the 24–10 grounds.

Portunus gibbesi (Stimpson)

Records of this species are confirmed by six specimens in my collection. Five crabs were taken in 10–11 fathoms off Pass Cavallo and the other in 11 fathoms east of Freeport, Texas. Gunter (1950) has previously reported it from off Port Aransas at ten fathoms. This crab also occurs among the rocks of the Port Aransas jetty. Both *P. gibbesi* and *P. spinimanus* are abundant in 6–10 fathoms off Campeche, Mexico.

Portunus spinicarpus (Stimpson)

This formidably armed portunid ranges from North Carolina to Brazil in 5–208 fathoms of water (Rathbun, 1933). It was encountered only along the seaward edge of the present brown shrimp grounds, and it is undoubtedly much more abundant in deeper water. In the large net 123 specimens of this species were counted. It was taken in depths of 15–45 fathoms. Nearly all crabs were small and no ovigerous ones were noted. It was most abundant in 31–37 fathoms on the 24–10 grounds.

Rathbun (1930) commented that this crab, although abundant at Tortugas, was not found in the stomach contents of several hundred fish. It has a long flattened swordlike spine on the inner angle of the carpus and the lateral spine of the carapace is also very long.

Callinectes sapidus Rathbun

Gunter (1950) and Daugherty (1952) have discussed the movements and distribution of the blue crab in the bays and the shore zone of the Gulf. Daugherty (1952) found that there was a gulfward movement of blue crabs through Cedar Bayou from March to July. This movement, predominantly of females, reached its peak during June and July. In August the number of crabs moving seaward was nearly balanced by crabs returning to the bays. He further states that the formation of egg masses occur mainly in the Gulf.

Blue crabs were taken during only three months of the year during this investigation, but most of my work was done beyond the expected seaward distribution of the blue crab.

Except for one large female caught in 3 to 7 fathoms of water off Greens Bayou, all blue crabs were caught during May, June and July. Two large females, one ovigerous, were taken in 17 fathoms offshore from Baffin Bay on May 12, 1951.

During July blue crabs were caught in 19 out of 21 drags made in 12–18 fathoms of water off Padre Island near 27° N. The greatest number in a single drag was 16. However, the blue crab is much more abundant inshore from the area fished. Sponge blue crabs were taken in minnow seines in the surf zone along the beach by laboratory personnel during the period of my investigation. Gunter (1950) found the greatest abundance of blue crabs on the Gulf beach during June.

The blue crabs captured during July were about 50 per cent ovigerous. The following measurements are taken from specimens caught in 12 to 15 fathoms on July 6, 1951, off Padre Island (near 27° N.).

6 ovigerous females. Carapace widths 130, 125, 120, 115, 103, 95 mm.
8 barren females. Carapace widths 126, 125, 119, 117, 115, 107, 100, 98 mm.

On the white shrimp grounds off Sabine, Texas, only eleven specimens were taken. None of these proved to be ovigerous females. Crab fishermen commented on the unusual abundance of berried blue crabs in Sabine Lake for that season of the year. The runoff from East Texas rivers was low, and although no salinity readings were taken, presumably the salinity was higher than in preceding years. Perhaps high salinity explains the comparative sparsity of the *C. sapidus* population in the shallow water off Sabine as compared to *C. danae*. The former is much more common in the bays (Gunter, 1950).

No blue crabs were taken in 12–23 fathoms of water off Grand Isle, Louisiana, nor were blue crabs found in 12 to 20 fathoms off Obregon, Mexico.

It is interesting to note that no male *C. sapidus* were captured in these offshore waters. This is consistent with the data presented by Gunter (1950) and Daugherty (1952) for Texas and earlier workers in the Chesapeake area.

Callinectes danae Smith

This little blue crab is the most abundant crab on the brown shrimp grounds and in the shallow offshore water of the northwestern Gulf. Gunter (1950) also reported it as the most common crab in the shallower waters of the Gulf where he worked. Approximately 89,000 crabs were recorded in the drags from which numerical data are available. An estimated 30,000 more occurred in drags not recorded numerically. These crabs were distributed as follows: 65,000 on the Texas grounds, 2,200 on the Louisiana grounds, 1,600 off Sabine, 3,200 on the 24–10 grounds, and 17,200 off Obregon. Of course, it must be noted that the number of drags and the seasons of trawling varied in the different localities, and these data are not strictly comparable.

No seasonal abundance trends were noted in the limited data at my disposal. Gunter found it most abundant in March to May. Fishermen believe that the Gulf crab is "chummed" into regions that are being heavily fished. When a strike of shrimp is first encountered, Gulf crabs are relatively rare. Some indication of this phenomenon is shown by my data for July. As the abundance of shrimp is reduced by fishing and the amount of trash fish dumped overboard increases, the catches of the scavenging Gulf crabs also increase. The writer had no opportunity to follow the fishing from the beginning of a "strike" until the end of heavy fishing. However, the large catches of

Gulf crabs during January may be some indication of this phenomenon because this fishing was done when the catches of shrimp in the area were declining rather sharply.

There is some differential movement according to sex and size. My data are insufficient to chart these movements, because information is available for only a limited bathymetric range. The following conditions were particularly noted. Sponge crabs were taken during all months of the year. Although numerical data were not kept, relatively more berried females were taken during the winter. Perhaps this may be due to the emigration of females outside the shrimp fishery grounds during the summer months. Sponges ranging in color from orange to black occurred during all months of the year. Sponge crabs were distributed between 3 and 40 fathoms, the depths fished. In addition a few sponge crabs were also taken in the surf on the Gulf beach by Institute personnel. Adult female crabs were rare in the area between 12 to 18 fathoms during July. A few counts of trawl catches indicated a ratio of 10 males to 1 female at that time. Gulf crabs with sponges varied in carapace width from 51 to 71 mm.

Males are larger than the females, which is not unexpected in the genus, *Callinectes*. The largest male had a carapace width of 93 mm. This large crab was caught in 18 to 24 fathoms of water off Corpus Christi during January.

A few small crabs were taken throughout the year. However, they were first noted particularly in the catch during May, when small crabs of 35 mm. carapace width were not uncommon. Most of the crabs observed off Sabine in six to seven fathoms of water were small, with carapace widths of 40 to 60 mm. Fully 30 per cent of the crabs in the July catch were small, 30 to 45 mm. carapace width, and in one drag the percentage increased to 60 per cent. The largest catch of small crabs was made in 12–14 fathoms of water during July.

C. danae is an important food for a large number of fish including the tarpon, *Tarpon atlanticus*, and the ling, *Rachycentron canadus*.

Arenaeus cribrarius (Lamarck)

Speckled crabs are widely distributed in the shallow coastal waters of the northern Gulf. In Texas it is common in a narrow belt paralleling the coast and it is often taken in minnow seines on the Gulf beach (Gunter, 1950). This crab was taken on three occasions in 3–6 fathoms off Greens Bayou during October, 1950. It was not taken off Sabine in 3–6 fathoms. Three specimens were taken in 14 to 15 fathoms off Obregon. Carapace widths of a male and a female speckled crab from Obregon are 118 and 80 mm. respectively.

Ovalipes ocellatus guadulupenis (de Saussure)

Gunter (1950) reported several specimens of this species from a few miles off the Aransas Pass jetties. No specimens of this crab were taken in Texas Gulf waters by me, although I have taken a juvenile in a pushnet in Aransas Pass. Approximately 103 specimens were counted in Louisiana, where one hundred crabs were caught in a single drag in 23–24 fathoms south southeast of Grand Isle, Louisiana. No ovigerous females were seen.

Xanthidae

Crabs as small as most of the mud crabs were not recorded, but they are very rare in large mesh shrimp trawls except under unusual circumstances.

Menippe mercenaria (Say)

Five stone crabs were captured from six fathoms of water off Sabine, when a rusty iron smokestack was caught in a trynet. One specimen, 49 mm. carapace width, was an ovigerous female.

Raninidae

Raninoides louisianensis Rathbun

Frog crabs were captured only on the 24–10 grounds in 31–37 fathoms. Two specimens were captured in the large net and several more in the small net.

Leucosiidae

Persephona crinita Rathbun

This little crab was taken only in 3–7 fathoms off Sabine. Only two specimens were found in the large net. It was taken in the trynet together with *P. punctata*. Ovigerous females were taken during June.

Persephona punctata aquilionaris Rathbun

Three specimens of this crab were taken in large trawls off Sabine and several other specimens in trynets off Sabine in 3–7 fathoms of water. It was slightly less abundant than *P. crinita* in the same area. Two specimens were also taken off Obregon in 14–17 fathoms of water. Ovigerous females were taken during June.

Calappidae

Hepatus epheliticus (Linnaeus)

A few specimens of this species were caught sporadically in trawls on the brown shrimp grounds in 12–19 fathoms. A total of 12 specimens was recorded in those depths. However, it appears to be much more abundant shoreward of the 12 fathom contour and Gunter (1950) reported specimens from the beach. Twenty-three calico crabs were recorded off Sabine and eight specimens off Greens Bayou in 3–7 fathoms of water. Strangely, ovigerous females were rare. One with a black sponge was noted on July 6, 1951 in 12–14 fathoms of water. The calico crab, as noted by Carlgren and Hedgpeth (1952), often carried the sea anemone, *Calliactis tricolor*, on the carapace.

Calappa springeri Rathbun

This large conspicuous crab is known as the rooster crab to Port Aransas fishermen. The claws are occasionally served as food by the Tarpon Inn at Port Aransas. This species was recorded in nearly every drag between 12 and 35 fathoms except off Obregon where it was rare. As only a few specimens occurred in each drag and the crab

is very conspicuous, it was possible to count all the crabs. A total of 387 rooster crabs were counted, 316 from the Texas grounds, 41 from the 24–10 grounds, 24 from Louisiana and 3 from Obregon. An additional three specimens were recorded from 3–8 fathoms off Greens Bayou during October.

A single ovigerous female was noted on May 14, 1951 in 21 fathoms of water off Padre Island. The smallest specimen measured 34 mm. (carapace width), and it was captured in 17–24 fathoms of water off Padre Island during May.

Echinodermata

Asteroidea

Phanerozonia

Astropectinidae

Astropecten antillensis Lutken

Occasionally, a few dozen small starfish were found in the big trawl, but thousands were taken in the trynet. Although trynet tows were not numerically recorded, there are repeated references in my field notes to the abundance of this little starfish. Sometimes as much as a gallon of starfish was caught in a single 15-minute drag. Little starfish were taken everywhere that brown shrimp were caught. It was uncommon off Sabine, Texas, in 3–7 fathoms, where only a few dozen specimens were seen. Only a few trynet drags were made on the 24–10 grounds in 30 to 37 fathoms, but this starfish was not taken in as great abundance as in 15–24 fathoms off the Texas coast.

Clark (1933) gives a maximum radius (center of disk to tip or arm) of 50–60 mm. All my specimens were much smaller and the maximum radius I found was 25 mm.

Astropecten cingulatus Sladen

This bright red starfish was noted only in 31–37 fathoms of water on the 24–10 grounds, where it was not uncommon. Since the original investigation I have taken this species in 25–26 fathoms off Mustang Island and fishermen have brought to the laboratory specimens from off the Texas coast in depths of 33 to 49 fathoms.

Tethyaster magnificus grandis Verrill

This starfish was found only on the 24–10 grounds and Obregon grounds. No measurements were taken, but several large specimens were taken on the 24–10 grounds in 31–37 fathoms. Four small specimens were taken in 17–19 fathoms off Obregon, Mexico. On February 15, 1954, I took one specimen with a radius of 167 mm. in 25–26 fathoms off Mustang Island.

Luidiidae

Luidia clathrata (Say)

The starfish fauna on the sandy Texas coast is very meager in numbers and species. This large *Luidia* is the commonest and the most conspicuous. It is sometimes taken in beach seines and often fragments drift ashore. Seven specimens were caught during this investigation. Six were caught on the Texas coast in 12–18 fathoms of water and two were caught off Obregon in 19 fathoms.

Luidia alternata (Say)

This starfish like the preceding one was rarely captured, but it was locally common. Thirty-five starfish were caught in 12–14 fathoms off Padre Island during July. Single specimens were taken during May in 11 fathoms east of Freeport, Texas, and in 3–7 fathoms off Sabine, Texas, during June, 1951.

Spinulosa

Echinasteridae

Echinaster echinophorus Lamarck

Clark (1933) reports three species of this genus from the Gulf of Mexico, and he says that the species of this genus are still confused. My material was identified by comparing it with starfish from Campeche. Only a single specimen was taken east of Freeport in 15 fathoms on shell bottom. This species is not uncommon on Campeche Bank.

Ophiuroidea

Fragile brittle stars are rarely encountered in the large trawls. Occasional fragments were not recorded.

Ophiolepis elegans Lutken

Several of these brittle stars were taken in 12–13 fathoms off Wine Island Pass. Four or five specimens from a single 15-minute trynet tow would indicate a rather large population.

Echinoidea

Exocycloida

Clypeastridae

Clypeaster ravenelli (Agassiz)

I am indebted to Dr. J. Wyatt Durham for the determination of this species. It has not been previously recorded from the Gulf. This species was found only in 24 fathoms north northeast of Brazos Santiago, where it was abundant. Fishermen report that it is most common in a V-shaped territory bounded on the north by a line running north northeast from the jetty at Brazos Santiago, and on the south by a line running south southeast from the jetty. The bathymetric distribution is not well understood because there is little trawling in the area, but sand dollars are locally common between the 20–30 fathom contours.

This sand dollar is abundant enough to hinder normal trawling operations. Trawling time must be cut in half, or the weight of large catches of sand dollars will weaken the trawling gear.

Scutellidae

Mellita quinquiesperforata (Leake)

This is the common shallow water sand dollar along the Texas coast. Often the white shrimp trawlers catch large numbers between two and three fathoms off the

Texas coast. This species was encountered in 3–6 fathoms off Greens Bayou, and along St. Joseph Island. No living specimens were caught in 3–7 fathoms off Sabine, Texas.

Spatangidae

Brissopsis alta Mortensen

Three or four times fragments of heart urchins were found in the trawl, but they were not specifically identified. In 14 fathoms off Wine Island Pass 12 specimens of *B. alta* and very little else was taken in a trynet drag. The fishermen say that it is not worthwhile to trawl for shrimp when heart urchins are found in abundance.

Holothuroidea

Stichopodidae

Stichopus badionotus Selenka

Three large specimens were caught in 18 fathoms south of Matagorda. This is predominantly a shallow water species and according to Clark (1933), it is normally found on eelgrass, *Thalassia*, flats.

Molpadiidae

Molpadia cubana Deichmann

This species was described by Deichmann from 150–285 fathoms off Cuba. Although records of the trynet catches were not always kept, it is improbable that more than eight specimens of this species were taken. It was taken in depths of 17–22 fathoms and appeared to be restricted to areas near shell bottom. For instance, all but one of my specimens were taken at the northern or southern edge of the Texas grounds, where the mud bottom is gradually replaced by shell.

Chordata

Tunicata

Ascidiacea

Stolidobranchiata

Styelidae

Ascidians were very rare in the trawl catches in the northwestern Gulf. A few sea onions, *Styela plicata* (LeSueur) and the smaller *S. partita* (Stimpson) were taken in 17–19 fathoms on the Texas grounds. According to Van Name (1945) this is at the seaward edge of their bathymetric range, as he has no records beyond 15 fathoms. *S. partita* was found attached to *S. plicata* and one time a small *Styela* was found attached to the leg of the spider crab, *Podochela sydneyi* (12–13 fathoms off Wine Island Pass). On February 16, 1954 a Small *Styela* was found attached to a flat lobster, *Scyllarides aequinoctialis*, which was captured in 25–26 fathoms off Mustang Island.

Gnasthostomata

Pisces

Chondrichthyes

Selachii

The voracity of sharks and their disdain for fishermen's nets is too well known to require elaboration here. Sharks damage much gear and what is even more important than the immediate loss of gear and catch is the time lost in repairing or replacing damaged gear. Shark damage was determined in two ways. If the net was being raised and the strain on the cables suddenly diminished, it was assumed to be due to sharks and it was so recorded. Sharks were also considered responsible for gear damage if the boat was operating in an area known to be free of wrecks or other obstacles. Examination of the tear itself, while it may be strongly suggestive of shark damage, is not always an infallible criterion.

How much damage sharks cause depends to a large degree on the fishing intensity. If many boats are operating and "feeding" the sharks by tossing trash overboard, the damage to nets is usually very slight. If only a few boats are operating, it often becomes necessary to suspend operations entirely because of shark damage. Mr. Felix Bruney, an Aransas Pass fisherman, estimated that he lost 100 barrels of shrimp during January, 1952 because of shark damage. At an average price of fifty dollars a barrel, this caused a decrease in income of five thousand dollars. The writer found that during approximately 562 hours of trawling, 20 hours or approximately 3.6 per cent of actual trawling time was lost because of shark damage. Shark damages, once in April and again in May, shortened fishing trips.

At first the writer thought that there was a seasonal distribution of severe shark damage. The first reports of heavy shark damage always came from the 24–10 grounds during January and February. Next heavy shark damage was reported from the south Texas coast during April and May. Finally damage was reported from the East Texas coast and Louisiana during May, June and July. Further analyses of these reports showed that chiefly they represent times and areas of active exploration for shrimp "runs." There may be a southward or an offshore concentration of sharks during the winter months and the reverse during the spring and summer, but my data from the shrimp fleet are insufficient to chart such concentrations.

What sharks are chiefly responsible for gear damage is not known. Springer (1951) mentions *Carcharhinus floridanus* as the common surface species in the blue water along the edge of the continental shelf. During May large numbers of spinner sharks were putting on a display around our shrimp boat by leaping clear of the water and spinning several times before they fell back into the water. Two specimens were caught on a hook and line and were identified as *Carcharhinus maculipinnis.* The largest specimen was 223 cm. long. These sharks were observed to feed at the surface on trash when it was dumped overboard. Large sharks are rarely caught in shrimp trawls. The largest caught during this investigation was a female *Carcharhinus milberti,* 8 feet long. Springer (in litt.) says that the tiger shark, *Galeocerdo cuvieri,* is probably responsible for a large part of the net damage. Although there were no tiger sharks taken during this investigation, there is a jaw of a large specimen (at least 8 feet long) in the collection of the Institute of Marine Science. It was taken in a shrimp trawl off Trinity Shoal in Louisiana during May, 1952.

Triakidae

Mustelus canis (Mitchill)

More smooth hounds were taken than all the other species of sharks combined. Catches of smooth hounds were not evenly distributed seasonally or by shrimping grounds. A total of 64 specimens was counted and they were distributed as follows: 13 from the Texas grounds, 1 from the 24–10 grounds, and 50 from the Obregon grounds. This shark is apparently most common around snapper banks (Springer, 1951). The writer also obtained this species on snapper banks at 24° 10′ N. and off Aransas Pass in 37 fathoms.

Baughman and Springer (1950) say that this shark is 14 to 15 inches long at birth. They reported a female with nearly fully developed embryos on March 24, 1940 off Freeport, Texas. In the northern part of its range the young are born during June and July. Very few adults were taken during the course of this investigation. One female about 4 feet long was taken on a snapper bank, Aransas Bank, on September 5, 1951. It had three embryos which appeared to be nearly fully developed. This would indicate the possibility of an extended breeding season in southern waters. Young sharks of approximately the size 14–15 inches at birth were taken off Aransas Pass in 18–21 fathoms on April 12, 1951 and off Obregon, Mexico, during July and August, 1951. Other small specimens, approximately 37 cm. long, were caught during May, 1951. In fact, except for two sharks, 75 and 90 cm. long respectively, all *M. canis* which were caught during May closely approximated 37 cm. in length.

Adult specimens were rarely caught. One adult female, 114 cm. long, was caught in 24 fathoms north northeast of Brazos Santiago. Another adult specimen 142 cm. long was caught in 18–19 fathoms off Obregon, Mexico.

In Texas this species is rare inshore, although it is sometimes taken in the inside waters of Louisiana (Fowler, 1933). I have not found this species among a large number of sharks examined on the Port Aransas jetties. However, it readily takes the hook and it sometimes becomes a pest on the snapper banks.

Carcharhinidae

Scoliodon terrae-novae (Richardson)

According to Baughman and Springer (1950) this small shark lives along the beach and is rarely caught more than a mile or two from shore. The writer has seen a number of these sharks which were caught by tourists from the Port Aransas jetties. During the spring of the year the young of this species together, with *Carcharhinus limbatus* are taken in considerable numbers by tourists, anglers and beach seiners along the Gulf beach.

Twelve specimens of this species were taken in 18–23 fathoms south southeast of Grand Isle, Louisiana. These were all adult specimens and the estimated lengths were 3 to 4 feet.

Aprionodon isodon (Muller and Henie)

Two specimens 18 inches long respectively were taken in 6¾ fathoms off the southwest buoy at Sabine Pass, Texas.

Carcharhinus acronotus (Poey)

Three specimens of this shark were caught in 14–19 fathoms off Obregon, Mexico. There is only a single specimen known from the Texas coast according to Baughman and Springer (1950).

Carcharhinus leucas (Muller and Henle)

Cub sharks are the most common shark in Texas waters according to Baughman and Springer (1950). Presumably, this is based on an investigation of the shark population with baited hooks as this species is rarely caught in trawls. One shark, approximately three feet long, was caught in a shrimp trawl in 10 fathoms of water off Pass Cavallo on December 11, 1951. No other specimens of this species were obtained.

Carcharhinus limbatus (Muller and Henle)

This is one of the common sharks in beach seine hauls along the coast of Mustang Island. Three specimens were found in the trawl hauls in 17–18 fathoms off St. Joseph Island during December, 1950. They were 3–5 feet in length.

Carcharhinus milberti (Muller and Henle)

A single large specimen was identified as this species, and this identification was confirmed by Stewart Springer. It was a large female nearly eight feet long. It contained nearly full term embryos, that averaged 24 inches in length. This is the first definite record of this species from Texas.

Carcharhinus obscurus (LeSueur)

This shark grows to a large size. My specimens were all small, 3–5 feet in length. Seven specimens were caught in 17–23 fathoms of water off Padre Island during May. One specimen was taken in 32 fathoms on the 24–10 grounds.

Carcharhinus porosus Ranzani

This shark enters the more saline bays of Texas and Weed obtained specimens in the lower Laguna Madre (Baughman and Springer, 1950). Three sharks of this species were observed in shrimp trawls during December, 1950. One was caught in 10 fathoms off Pass Cavallo. It was approximately three feet long. Two other specimens were taken in 18 fathoms off St. Joseph Island. Four specimens were taken in 24 fathoms north northeast of Brazos Santiago during March, and two specimens were taken in 15–19 fathoms off Obregon, Mexico. All specimens were less than five feet long.

Sphyrnidae

Sphyrna tiburo (Linnaeus)

The shovel-nosed shark is well known to anglers along the jetties at Port Aransas, Texas. However, there are weeks when none or very few are caught at Port Aransas. Undoubtedly, there is an offshore migration during the winter, but the writer has not collected adequate data to define it. Gunter (1945) obtained a few specimens in spring,

summer and fall. He says (personal communication) that it is probably the commonest shark in Texas bay waters. Two specimens were taken in November in 17–19 fathoms off Padre Island and two were taken in 17–19 fathoms off St. Joseph Island during December. One specimen was taken in 24 fathoms off Corpus Christi Pass during January, 1951 and it is the deepest record I have. One specimen had eaten Gulf crabs, *C. danae*. Springer (1938) and Gunter (1945) have noted the crab-eating predilection of this small shark.

Sphyrna diplana Springer

Only four specimens of the common hammerhead were seen. It was not taken in trawls along the Texas coast, although the writer has often seen it in the anglers' catches on the Port Aransas jetties. Two specimens were taken in 32–40 fathoms on the 24–10 grounds. During the winter months hammerheads are often taken in the shrimp trawls in that region. Two other small specimens were taken off Obregon, Mexico in 17–19 fathoms of water during August, 1951. None of my specimens exceeded five feet in length.

Sphyrna tudes (Cuvier)

One specimen of the great hammerhead was taken off St. Joseph Island during December, 1950 in 18 fathoms of water. This species has been known from the Texas coast only from a photograph. My specimen was identified on the basis of serrated teeth in both jaws. It was a small shark under five feet in length.

Squatinidae

Squatina dumerili LeSueur

Monkfish occur on the seaward edge of the present fishery, and consequently are rarely caught by shrimp fishermen. Six specimens were caught as follows:

Dec. 19, 1950, 1, 23–25 fms. South of Greens Bayou, Texas.
March 6, 1951, 1 female, 74 cm. 21–31 fms. 60 miles south of Port Isabel, Texas.
March 9, 1951, 1, 64 cm. 32 fms. 100 miles south of Port Isabel, Texas.
March 10, 1951, 1, 94 cm. 32–34 fms. 100 miles south of Port Isabel, Texas.
May 5, 1951, 1 male and 1 female, 22 fms. Off Pass Cavallo.

One specimen had eaten a sand trout, *Cynoscion nothus*.

Batoidea

Pristidae

Pristis pectinatus (Latham)

One large sawfish was caught in a shrimp trawl a few miles north of Sebree Bank in 17½ fathoms of water on November 17, 1950. This sawfish was about 10 feet long (including the saw). Extensive net repairs were necessary after the sawfish was removed.

Rhinobatidae

Rhinobatus lentiginosus (Garman)

Guitarfish are not uncommon in the shallow water near shore. Twenty-seven specimens were taken in 3–8 fathoms of water between Pass Cavallo and the Colorado

River. A single specimen, 640 mm. long, was caught off Sabine in 6½ fathoms.

All Texas specimens were brown, while specimens caught off Campeche had the typical spotted pattern. These color differences were pointed out to me by Gunter before this investigation started, and I found no exceptions. One specimen was taken off Pass Cavallo in 16 fathoms of water. This is the greatest depth at which I found this species.

Rajidae

Raja olseni Bigelow and Schroeder

A single specimen of this black skate was taken in 32–33 fathoms off 24° 10′ N. It was a male, 500 cm. long. This recently described species apparently replaces the common *R. texana* in water of more than 40–50 fathoms deep.

Raja texana Chandler

Until the large trawlers came to the Texas coast, this was considered to be a very rare skate. Gunter (1945) reported four specimens. It is, indeed, rare in the shallow coastal waters fished by the sportsmen. I have seen only one specimen caught off the Port Aransas jetty during nearly two years of sporadic observations. However, in depths of 10–30 fathoms it is ubiquitous, as my trawling results show. If all depths of less than seven fathoms are excluded, the Texas skate was taken in every drag successfully completed. It was never abundant and only 1,233 specimens were counted. On the brown shrimp ground proper it was caught at the rate of two to three specimens an hour. The catch of Texas skates was distributed as follows: 900 from the Texas grounds, 67 from Louisiana, 59 from the 24–10 grounds, 122 from Obregon, and 85 from the white shrimp grounds between Pass Cavallo and the Colorado River. This skate was found in smaller numbers in the 31–40 fathom area trawled than in the 15–24 fathom zone.

Very little information was gathered on the habits of this skate. Two egg cases, which probably belong to this species, were found in 23–25 fathoms of water south of Greens Bayou during December, 1950. Gunter (1945) reported egg cases in March. The smallest skate was 97 mm. long. It was caught in 24 fathoms of water north northeast of Brazos Santiago on March 15, 1951. About 10 per cent of the specimens caught during May were under 150 cm. in length, and fully 75 per cent of the July captures were small skates.

Torpedinidae

Narcine brasiliensis Olfers

Predominantly, the torpedo ray is a shallow water animal and is rarely taken in water deeper than 10 fathoms. Mr. W. C. Schroeder, who is engaged in a revision of the batoid fishes of the Western Atlantic, informs me that my specimens from 32 to 37 fathoms off northeastern Mexico represent a new depth record for the species. This species was found moderately common in 3–8 fathoms of water in the territory between Pass Cavallo and the Colorado River during October, 1950. One specimen was taken in 17 fathoms off Sebree Bank on November 17, 1950. Eight were taken on the 24–10 grounds in depths of 21–32 fathoms during March. Three specimens were caught in

3–7 fathoms off Sabine during June and a single specimen was taken in 12–14 fathoms off Padre Island during July, 1951.

Dasyatidae

Dasyatis sabina (LeSueur)

This is the common inshore stingaree (Gunter, 1945). This species leaves the bays in the fall of the year, and its movement gulfward is accelerated by the cold northers. At this time a large number are caught by tourist anglers along the jetty at Port Aransas, Texas.

No specimens were caught on the brown shrimp grounds, but it was not uncommon in depths of 3–8 fathoms between Pass Cavallo and the Colorado River, where it was recorded in all drags. It was also encountered on the white shrimp grounds off Sabine during June.

Dasyatis sayi (LeSueur)

Gunter (1945) reported *Dasyatis americana* as the common large stingray in the bays and shallow Gulf. If this species was taken at all during this investigation, it was not recognized. Large stingrays were rare and, moreover, they are too large to bring back to the laboratory for study. Large stingrays are dropped overboard immediately so that sorting of the catch can commence. In a few cases my notes proved inadequate to positively identify the stingray, so one or two *D. hastatus* may be included under the account of this species.

Ten large stingrays were counted. All, except one caught off Sabine, are from depths greater than 15 fathoms. One specimen, possibly *D. hastatus,* was caught in 24 fathoms north northeast of Brazos Santiago. The wingspread of this ray was 5 feet. A specimen nearly as large was caught in 19 fathoms off Obregon. It had probably been previously caught by a shrimp trawler as the stinger had been removed.

Pteroplatea micrura (Schneider)

Next to *R. texana* the butterfly ray is the most abundant batoid in the area trawled. This species was caught at all depths and in all localities trawled. Large specimens were more common in deep water. It is rarely taken in bay waters (Gunter, 1935). The catch of 111 butterfly rays were distributed as follows: 73 from the white shrimp grounds along the Texas coast, 12 from the Texas grounds, 9 from the Obregon grounds, 3 from the Southwest Pass grounds and 14 from the 24–10 grounds.

Osteichthyes

Isospondyli

Clupeidae

Sardinella anchovia (Cuvier and Valenciennes)

There are no records of this species from the Texas coast, and I did not find it there. This clupeid is abundant on the Campeche Bank in 6–10 fathoms of water. Nine specimens were taken from trawl catches off Obregon, Mexico. Two *S. anchovia* were 176

and 186 mm. long respectively. Several other specimens were taken from the stomach of a lizardfish, *Synodus foetens,* which was caught off Obregon, Mexico.

Harengula pensacolae pensacolae (Goode and Bean)

This sardine was not abundant in the trawl catches and it was not taken in depths greater than 19 fathoms of water. Gunter (1950) has shown that this species is common along the Texas shore from April to November. A shrimp trawl is not suitable for capturing this species, and it may migrate toward the surface at night, thus making its capture even more unlikely on the brown shrimp grounds. The majority of the specimens observed were taken during July in 12–15 fathoms off Padre Island. One hundred and thirty-seven specimens were counted, 88 on Texas grounds, 12 Southwest Pass grounds, 23 off Obregon, and 14 on the white shrimp grounds off Sabine, Texas.

Opisthonema oglinum (LeSueur)

Thread herring comprise a very small percentage of the catch by menhaden fishermen, according to Miles and Simmons (1950). Twelve specimens were taken in trawls in 6½ fathoms of water off Sabine. This species was common on Campeche Bank during February, 1951. Gunter took only three among some ten thousand fishes trawled in the shallow Gulf.

Brevoortia patronus Goode

Shrimp trawls are not suitable for capturing this pelagic fish, and yet at times when large schools of menhaden are encountered, so many are caught that trawls burst under the weight of menhaden. No schools of menhaden were sighted during this investigation. A few menhaden were taken on the white shrimp grounds. Fourteen specimens were taken in 17 fathoms off St. Joseph Island on December 9, 1950 and one menhaden was caught in 18 fathoms off Corpus Christi Pass on January 4, 1951.

Engraulidae

Anchoa hepsetus (Bonnaterre)

Anchovies easily escape through the big mesh of shrimp trawls. Only a few handfuls of this species were seen. Anchovies were not caught in depths greater than 19 fathoms, and they were caught on the Texas, Southwest Pass and Obregon grounds.

Anchoa mitchilli diaphana Hildebrand

This species like the preceding one can escape through the meshes. Except for one interesting capture, all specimens of this species were taken on the white shrimp grounds off Sabine. One specimen together with *A. hepsetus* was caught in 17 fathoms off Padre Island on May 19, 1951. This specimen is in the collection of the Institute of Marine Science. Gunter (1945 and earlier) has shown that it is extremely abundant in the bays and that possibly it has the greatest species mass of any shallow water fish.

Apodes

Congridae

Congrina flava (Goode and Bean)

All specimens of this eel were captured on the brown shrimp grounds in 12–31 fathoms. Eleven eels were recorded, but if the net had been shaken thoroughly each time it was hauled aboard, more specimens might have been obtained. Three large specimens, 1,138, 965 and 831 mm. respectively, have been tentatively referred to this species. These specimens were taken off St. Joseph Island in 15–19 fathoms.

The rest of the specimens ranged in length from 80 mm. to 321 mm. The 80 mm. specimen was found in the stomach of a frog fish, *Antennarius radiosus*. One large specimen, 965 mm. long, had fragments of an eel in its stomach.

Dysomma aphododera Ginsburg

Again it is nesessary to emphasize the inadequacy of shrimp trawls for capturing eels, as many escape through the meshes. This recently described eel was taken in 11 different drags on the Obregon Grounds. Three other specimens were taken in 31–37 fathoms on the 24–10 grounds. The Obregon specimens ranged in length from 150–316 mm. Two eels had eaten stomatopods, *Squilla empusa*, and if this is their normal food, a large supply is readily available.

Neoconger mucronatus (Girard)

The type locality of this species is St. Joseph Island. One specimen of this eel was taken from the stomach of a batfish, *Ogcocephalus*. The batfish was caught in 15 fathoms of water off St. Joseph Island. One additional specimen was found dead on the shore of Aransas Pass on February 1, 1951 after a freeze. This small eel is rarely seen, and its center of greatest abundance on the Texas coast is still unknown.

Hoplunnis macrurus Ginsburg

This slender, long-snouted eel is one of the most characteristic fish on the brown shrimp grounds. Its size and shape make it rather difficult to capture. Most specimens are trapped in the webbing along with sargassum at the point of attachment of the lazy line with the cod-end. The 213 specimens captured are, therefore, not indicative of the true abundance of this species. This species was caught in all areas fished, where the water was deeper than 12 fathoms.

Our specimens ranged in length from 160–431 mm. Females with eggs were noted in January and again during May. The food of this fish consists chiefly of small juvenile fish. Fish identified in the stomach contents were cusk eels, *Lepophidium*, and anchovies, *A. hepsetus*. One specimen contained a small shrimp, *Trachypeneus similis*.

Uroconger sp.

This eel has not been previously reported from the Gulf of Mexico. Four specimens were caught, two in 24 fathoms north northeast of Brazos Santiago, one in 17 to 19 fathoms off Obregon, Mexico, and one in 18 fathoms off Padre Island during July,

1951. An eel 319 mm. long which was caught off Obregon, Mexico had eaten another eel, *C. flava.*

Ophichthyidae

Mystriophis intertinctus (Richardson)

A single badly damaged specimen of this genus was taken from the webbing of trawl off Corpus Christi Pass. The depth of water was 23½ fathoms and a large number of *Busycon* conchs were found in the ripped trawl.

According to Ginsburg (1951) the best character for keying the three species of *Mystriophis* in the Gulf of Mexico is the size of the spots. As there is no comparative material in the collection of the Institute of Marine Science, the identification of this eel is tentative.

Ophichthus gomesi (Castelnau)

A snake eel, 31 cm. long, was found among a large number of croakers, *Micropogon undulatus, and* cutlass fish, *Trichiurus lepturus.* This eel was caught in seven fathoms of water off Sabine, Texas during June, 1951. I have seen additional specimens of this eel caught on hook and line off the jetties at Sabine, Texas, and from the dock of the Institute of Marine Science at Port Aransas, Texas.

Muraenidae

Gymnothorax nigromarginatus (Girard)

Next to *H. macrurus* this was the most abundant eel in trawl catches. This species is often found on mud bottom, but it appears to be more abundant in regions adjacent to shell banks. Thirty-four specimens were taken, 24 on the Texas grounds, 6 on the 24–10 grounds and 4 on the Obregon grounds. It was caught in depths of 12 to 34 fathoms.

No specimens with ripe gonads were seen. In contrast to most of the other fish in the trawls this species usually had food in the stomach. Six specimens contained large shrimp, *P. aztecus.* Another had eaten a squid and still another had eaten a small blue crab, *C. danae.* Apparently this species regularly feeds at night.

Nematognathi

Ariidae

Bagre marina Mitchill

Gafftops are regularly marketed in east Texas, but there is only a sporadic market in south Texas. Several times during the winter of 1950–51 the fish buyers in Aransas Pass were unable to dispose of even the small quantities which shrimp trawlers had brought into port.

Gafftops were noted as the most abundant fish in 3 drags made in 3–8 fathoms between Greens Bayou and the mouth of the Colorado River. These fish were probably leaving the bays together with the white shrimp. These data corroborate Gunter's re-

sults. He found the most gafftops in the Gulf near the passes during October and November and stated that they leave the bays in winter.

A few gafftops were seen on the brown shrimp grounds during the winter months only. The catches were distributed as follows: 12 in 17–19 fathoms, a few miles north of Sebree Bank during November, 1950; 40 in 24–25 fathoms south of Greens Bayou during December; 9 in 17 fathoms off St. Joseph Island during December; 136 in 17–25 fathoms off Corpus Christi Pass during January; and 8 in 21–31 fathoms, 60 miles south of Port Isabel during March. These were all large gafftops.

Fishermen reported large concentrations of gafftops in 24–25 fathoms south of Greens Bayou during early December, 1950. One fisherman estimated that he caught nearly two tons in one drag (4 hours). Another fisherman reported a catch of over a thousand pounds in 20–24 fathoms off Aransas Pass after the big freeze of January 28 to February 3, 1951. It appears that the gafftop leaves the bays early in the fall and moves to deeper water on the continental shelf. Very few are present in the shallow water and consequently, this species, unlike the hardhead, is little affected by cold northers.

One 375 mm. specimen with enlarged gonads was taken on January 23, 1951 in 20–22 fathoms. Gudger (1918) and Gunter (1945) gave evidence of spawning in May.

Galeichthys felis (Linneaus)

The hardhead was not common on the brown shrimp grounds during the winter. Seventeen specimens were observed in 17 fathoms off St. Joseph Island in December and an additional 48 specimens were taken in a single drag in 24 fathoms off Corpus Christi Pass during January.

This species was common along the Gulf beach off Sabine, Texas during June, 1951, when 975 specimens were recorded in the shrimp trawl. Although length-frequency data were not taken, many of these catfish were small. In the early fall very few *G. felis* were taken along the beach in 3–8 fathoms off Greens Bayou during October. Gunter (1945) found the greatest increase in the number of hardheads on the Gulf beaches during the month of November. He has shown that the hardhead spawns in the less saline portions of the Texas bays, often far from the passes. An interesting anomaly is shown in my data. One hundred and sixty-three hardhead catfish were taken in depths of 12–15 fathoms off Padre Island during July. These were all adult but unfortunately careful observations were not made on spawning conditions. No males were noted with eggs in their mouths, but large females with large ovarian eggs were noted. This locality is rather an unusual one as the pilot chart for June shows a convergence of three currents. Possibly, these catfish were unable to find their way to the passes, and whether they could successfully spawn in the open Gulf is not known. The time of capture would be at the end of the spawning season according to Gunter (1947).

Iniomi

Synodontidae

Lizardfish were almost ubiquitous and appeared in nearly every drag. Unfortunately, the young of three species, *S. foetens*, *S. poeyi*, and *Saurida brasiliensis*, were not always distinguished correctly so the numerical data have been lumped. The 18,440

lizardfish were counted: 9,800 on the Texas grounds; 1,025 on the Southwest Pass grounds; 2,340 on the 24–10 grounds; and 5,275 on the Obregon grounds.

Synodus foetens (Linnaeus)

This is the common inshore lizardfish on the Texas coast and it is estimated that at least 75 per cent of the lizardfish caught belonged to this species. It is the only species taken in the bays and shallow Gulf, and larval specimens even penetrate the back bays (Gunter, 1945). No special seasonal trends were noted in the distribution of this species.

This species eats a variety of animals. Squid, *L. pealei*, flatfish, *Syacium gunteri*, clupeids, and shrimp were observed in the stomachs. However, many of the fish captured during the night had not been feeding.

This lizardfish has a tendency to gill in the meshes of the trawls. Large specimens must be pulled from the net when it is cleaned and hung up to dry. The odor of this fish after a few hours in the Texas sun leaves no doubt as to the fitness of its scientific name.

Synodus poeyi Jordan

This distinctive little lizardfish has larger, more silvery scales, larger eyes and a shorter snout than does *Synodus foetens*.

There are specimens of *S. poeyi* in the collection from the following localities: 17–19½ fathoms off St. Joseph Island during December, 1950, 32–37 fathoms off the 20–10 grounds during March and 17–23 fathoms off Padre Island during May. This species is most abundant in depths greater than 17 fathoms. During May it was probably as abundant as *S. foetens*. Evidently it moves shoreward during the summer months. Later investigations have shown this species to be common (500 specimens from 18 hours of trawling) in 25–26 fathoms off Mustang Island during February.

Saurida brasiliensis Norman

This species was certainly the rarest of the three species of lizardfish in the northwestern Gulf. There are small specimens of this species in the collection from the following localities: 32–37 fathoms on the 24–10 grounds during March, 24 fathoms off Corpus Christi Pass during January, and from 12–18 fathoms off Padre Island during July. The specimens in my collection range from 38–95 mm. in length.

Trachinocephalus myops (Forster)

The snakefish is a characteristic fish of the white shell sand of Campeche Bank. It is very common there in depths of 6–10 fathoms. This species has not been reported from the Texas coast.

Ten specimens were taken in 19–20 fathoms off Obregon, Mexico. It was recorded only in a single drag.

Anacanthini

Bregmacerotidae

Bregmaceros atlanticus Goode and Bean

Four small specimens of this genus were seen and are in the collection of the Institute of Marine Science. These specimens are as follows:

1 Tl 71 mm. 23 fathoms off Corpus Christi Pass, January 23, 1951.
1 Tl 28 mm. 31–37 fathoms 100 miles S. of Port Isabel, March, 1951.
1 Tl 52 mm. 21–23 fathoms off Southern Padre Island, May 16, 1951.
1 Tl 53 mm. 18 fathoms off Obregon, Mexico, August 5, 1951.

Gadidae

Urophycis floridanus (Bean and Dresel)

Gunter (1945) has summarized the information on this species. It moves into the bays in Louisiana and Texas during the winter and leaves again in the spring. There is evidence that they move into the bays after sharp drops in temperature and remain in the bays throughout the coldest months of the year.

No information was gathered from the inshore waters during the winter months, but no specimens were taken offshore in depths of 10–24 fathoms during November, December and January. This species was first encountered in 21 fathoms of water 60 miles south of Port Isabel on March 5, 1951.

Hake were caught most abundantly during April and May. Apparently they were common in the 17–24 fathom zone from the Colorado River to Sebree, as they were found in three widely separated localities during April and May. For example, 40 specimens were taken in a single drag east of the Port Aransas jetties in 18–21 fathoms during April, another 76 fish were taken in 19–22 fathoms off Matagorda Peninsula and 242 off Padre Island in 17–24 fathoms during May. Two hakes were caught in 19–23 fathoms off Grand Isle, Louisiana, during June. Only 9 specimens were taken during the extensive trawling operations of July, 1951, in 12–18 fathoms off Padre Island, presumably because most of the hake spend the summer in deeper water.

Few measurements were taken. April specimens were relatively large, 215–222 mm. in length. Fish caught during May ranged from 101–171 mm. and those caught in July ranged from 154–211 mm. One specimen examined during May had eaten a small porgy, *Stenotomus caprinus*.

Heterosomati

Bothidae

Paralichthys albigutta Jordan and Gilbert

Ginsburg (1952) has listed three closely related species of the genus *Paralichthys* which may be expected in the shallow water of the western Gulf. *P. squamilentis* was recorded by Ginsburg on the basis of three small specimens from Corpus Christi Pass. This species was not detected in our catch and according to Springer (1951) the adults are most abundant between 60 and 120 fathoms. Both *P. albigutta* and *P. lethostigma* were taken during this investigation, but only two specimens of *P. albigutta* were

recognized. One specimen was collected in 19–23 fathoms south southeast of Grand Isle, Louisiana, on mud bottom. The other specimen was taken in 12–18 fathoms off Padre Island (27° N.) during July. Ginsburg (1952) states that *albigutta* prefers a sand bottom and he did not find this species in the inshore area between the Atchafalaya and the Mississippi Rivers. However, Gunter (1945) took this flounder on mud bottom and the fish is not very common on the sandy beaches of the Gulf. Gunter caught 12 *albigutta* to 241 *lethostigma* and my data indicate that this species is rare in Texas waters.

Most of the trawling during this investigation was over mud bottom and in water deeper than 12 fathoms. The work of Ginsburg and Gunter show that the young and adults of both species occur in the bays and shallow water of the Gulf. There is little information on the bathymetric distribution of either species but it is probable that the adults of *P. albigutta* have a preference for shallower water.

Paralichthys lethostigma Jordan and Gilbert

Fishermen on the Texas coast refer to this species when they speak of flounder. During the fiscal year 1949–50, 181,000 pounds of flounder were caught in Texas waters by commercial fishermen, of which 16,465 pounds were caught in shrimp trawls, according to the statistics of the Texas Game and Fish Commission. Flounders find a ready market in Texas and all flounders above the legal size limit of 12 inches are saved for the market by shrimp fishermen. Shrimp fishermen complain that flounders are now scarce on the shrimp grounds, and that when they first started fishing for brown shrimp they could always catch enough flounders to pay the grocery bill. However, the catch of flounders during 1949–50, one of the early years of the brown shrimp fishery, would indicate a sparse population on the brown shrimp grounds.

For a long time it has been known that most of the flounders leave the bays for the Gulf during the fall of the year. It is at this time that flounders are gigged in greatest numbers on the flats around the passes and they may be easily taken in set nets.

In my fishing log no breakdown is given for the different species of *Paralichthys.* Although every flounder could not be examined closely, it seemed that the percentage of any other species besides *lethostigma* was small. In fact only two specimens of *albigutta* were detected. A number of anal ray counts were made to confirm my field identifications and in all cases the count ranged from 68–70, except for the two specimens of *albigutta* which had 64 rays.

Ginsburg (1952) states that the range of this species extends from Albemarle Sound, N. C., to Corpus Christi Pass, Texas. Flounders are not uncommon off Padre Island and I took one flounder, 355 mm. long, in 32–34 fathoms on the 24–10 grounds nearly a hundred miles south of the Rio Grande. No species of *Paralichthys* were seen in 6 to 10 fathoms off Campeche during February, 1951, nor off Obregon in 13 to 20 fathoms during August. However, the absence of flounders from Obregon is not proven, as most of the flounders should be inshore of the area trawled at that season. Mather (1952) did not report this genus from the Carmen area, although most of his work was done with sport fishing gear.

Six hundred and forty-six flounders were counted, 442 on the Texas grounds, 198 in Louisiana, six on the white shrimp grounds off Sabine and one on the 24–10 grounds. The bathymetric range of *lethostigma* off the Texas coast is unknown. I took 15 flounders 12 to 15 inches long in 26 fathoms of water off Mustang Island during

February, 1954. This is the greatest depth that I have trawled along the Texas coast. Flounders were much more abundant during November, December and January than during May and July on the Texas grounds. Nearly every winter drag contained at least a few flounders, but this was not so during the spring and summer. The largest catches were made during December south of Greens Bayou in 18–24 fathoms and during June in 19–23 fathoms off Grand Isle.

Most of the flounders were large, but at times a number of flounders 8–12 inches long are caught. This was noted particularly during December off Matagorda and again during June off Grand Isle, Louisiana. These small flounders are almost always dead when brought on deck, but they must be discarded as too small to legally market.

Ancylopsetta dilecta (Goode and Bean)

One small specimen was taken in a trynet from 31–35 fathoms on the 24–10 grounds. Recent surveys in the Gulf of Mexico have shown that this species is common in deeper water than that now fished. One specimen, 165 mm. long, caught in 33–49 fathoms southeast of Port Aransas, Texas, was given to the Institute of Marine Science by a shrimp fisherman.

Ancylopsetta quadrocellata Gill

One hundred and forty-eight ocellated flounders were counted, 91 on the Texas grounds, 1 on the 24–10 grounds, 1 on the Obregon grounds, and 30 on the Southwest Pass grounds. Apparently, this species never concentrates in large numbers anywhere in the western Gulf. It was definitely recorded from 24 fathoms south of Greens Bayou, and it was taken in water as shallow as 3 fathoms.

This is a small flounder. The largest measured was 297 mm. (approximately 12 inches). Only small ocellated flounders, ranging in length from 112 to 128 mm., were taken in 3–7 fathoms off Sabine during June.

Syacium gunteri Ginsburg

Sportsmen protest bitterly against the destruction of small flounders by the trawlers, but most of these protests are invalid as it is this little flounder which is destroyed and not the commercial and sport fish, *P. lethostigma*. Thousands of small Syaciums are caught every day by the shrimp trawlers. Not a single drag on the brown shrimp grounds in the western Gulf was free of this little flatfish. It is the most common flatfish and the most common fish, as well, on the brown shrimp grounds, as Anderson and Gunter have previously noted. This species declined landward of the 10 fathom contour and it is unreported from the bays. Its maximum bathymetric range is unknown, but it probably does not exceed 100 fathoms.

Approximately 66,000 *Syacium* were counted, 52,600 on the Texas grounds, 4,300 on the Obregon grounds, 8,200 on the 24–10 grounds and 3,120 on the Louisiana grounds. A few specimens were taken in 3–8 fathoms off Greens Bayou during October, but they were not counted. This species was not found in the 3–7 fathom zone off Sabine during June, 1951.

As previously mentioned, this is a small species in western Gulf waters, and the largest fish measured was 178 mm. No pattern was discernible in the distribution of

the young. Fish as small as 68 mm. were taken in 24 fathoms during December, 1950. Very little information was gathered on the food of this species. Several specimens were seen that had eaten small triglids, *Prionotus stearnsi.*

Cyclopsetta chittendeni Bean

This species has been called the Mexican flounder by the fishermen. Perhaps, this is because the large adult flounders are found in depths greater than 20 fathoms, and it is on the northeastern coast of Mexico that the deepest fishery for brown shrimp is prosecuted. A few of the large fish are found in the markets in south Texas, but it has a very limited sale. Many of the large specimens are infested with nematode and cestode parasites.

Approximately 18,390 Mexican flounders were counted, 13,732 on the Texas grounds, 1,925 on the Southwest Pass grounds, 1,958 on the 24–10 grounds and 775 on the Obregon grounds. This species is very rare landward of the 10 fathom curve. It was taken only once during October in depths shallower than 10 fathoms, and it was not found in 3–7 fathoms off Sabine during June, 1951. Specimens ranged in length from 100–320 mm., but as the otter trawl was inadequate for capturing the small young, little can be said about their distribution except that the young were more common in the shallower depths fished (12–20 fathoms). This fish eats small fishes to some extent, but most of the stomachs examined were empty.

A few small specimens approach the coloring of *C. decussata* Gunter, and it is probable that this name is a synonym of *chittendeni.*

Citharichthys macrops Dresel

Little is known of the distribution of this species in the western Gulf. Gunter (1945) did not find this species in the Texas bays, although he took two specimens in the open Gulf. I found many *C. macrops* on the hard shell sand bottom off Campeche, Mexico. Perhaps this species prefers a hard sand substrate in contrast to *Citharichthys spilopterus,* the common species on the Texas coast.

I recorded this species in only four drags. Except for one capture in 16 fathoms off Matagorda Island, all captures, 25 in all, were made in depths of 12–23 fathoms on the Louisiana grounds. The bottom was listed as mud, but it well may be that some time during the drag solid sand bottom was crossed, particularly in 12–13 fathoms off Wine Island Pass.

Citharichthys spilopterus Günther

Gunter (1945) reported this species as common in the Texas bays. It occurs offshore commonly out to 12 fathoms. Specimens are sporadically taken out to 24 fathoms, and there is one specimen in the Institute of Marine Science collection which was taken in 40 fathoms off Louisiana by the "Oregon."

Two thousand three hundred and fifty whiffs were counted, 1,810 on the Texas grounds, 530 on the Louisiana grounds, 1 on the Obregon grounds and 11 in 3–7 fathoms off Sabine, Texas. This species is probably more abundant in the deeper water during the winter time, although my data are inadequate to show the extent of migration. Gunter found none in Texas bays in midwinter. No *C. spilopterus* were caught in depths greater than 18 fathoms during May, whereas they were not un-

common during December. The largest catch in a single drag was 450 in 10–11 fathoms off Pass Cavallo on December 11, 1950. One specimen, 128 mm. long, was caught in 16–18 fathoms off Obregon, Mexico. No others were discovered at Obregon although a careful search was made for this species.

Etropus crossotus Jordan and Gilbert

The fringed flounder is one of the small flounders which abound in the shallow water of the western Gulf. It is a shallow water species and rarely occurs at depths greater than 17 fathoms.

Approximately 776 fringed flounders were counted, 621 on the Texas grounds and 155 on the Louisiana grounds. This species was not seen off Obregon, although it is common in 6–10 fathoms off Campeche, Mexico.

Trichopsetta ventralis Goode and Bean

This distinctive flatfish was found only along the seaward edge of the present brown shrimp fishery. There may be a small shoreward movement during the spring, as it was taken in 18–24 fathoms during April and June and it was not taken during December and January in approximately the same locality. Five hundred and eighty-one were counted, 448 on the 24–10 grounds and 133 on the Texas grounds.

Engyophrys sentus Ginsburg

Engyophrys sentus, the smallest Texas flounder, is not uncommon in the Gulf at depths greater than 15 fathoms. Its abundance may be much greater than is shown in the trawl catch as the gear was inadequate for its capture. The occurrence of this species in the western Gulf has been summarized by Anderson and Lindner (1941).

Approximately 1,900 small flounders were counted, 1,536 on the Texas grounds, 53 on the Obregon grounds and 325 on the 24–10 grounds. These flounders ranged in length from 40–78 mm. One female, 68 mm. long (standard length), with ripe ovaries was seen on May 13, 1951.

Achiridae

Achirus fasciatus Lacepede[1]

Hogchokers and lined soles, *Achirus sp.*, are common shallow water species in the northern Gulf. Gunter (1945) has summarized their occurrences in the bay and Gulf. The genus, *Achirus*, was encountered during this investigation in the months of October and June. During October I did not attempt to identify the species in the field and all log entries are simply *Achirus*. However, achirids were the most abundant flatfish at times in depths of 3–6 fathoms off Greens Bayou.

Fourteen specimens were taken in 3–7 fathoms off Sabine, Texas. I was surprised at the capture of this species in 19 fathoms south southeast of Grand Isle in Louisiana.

[1] See Hildebrand and Cable (1938) concerning the use of this name in preference to *Trinectes maculatus* of some authors.

Achirus lineatus (Linnaeus)

The only occurrence of this species was in 3–6 fathoms off St. Joseph Island and Matagorda Island and peninsula during October. No numerical observations were made.

Gymnachirus texae (Gunter)

At one time the black-lined naked soles were very rare in collections. A number of species were described on the basis of a single specimen. While the taxonomic status of these soles is still not clear, the name *G. texae* has been the only one specifically applied to Texas specimens and all specimens seen from Louisiana and Texas correspond to Gunter's description.

Approximately 1,433 specimens of this sole were counted, 674 on the Texas grounds, 173 on the 24–10 grounds, 586 on the Obregon grounds, and one specimen was obtained in 12–13 fathoms off Wine Island Pass, Louisiana, in a trynet. Size differences were noted in the catch; for example, July specimens ranged from 63–91 mm. while January specimens ranged from 116–130 mm. in length. Ripe females were seen during March on the 24–10 grounds. One female, 116 mm. long, from the 24–10 grounds had enlarged ovaries that seemed nearly ripe.

Cynoglossidae

Symphurus civitatum Ginsburg

When this investigation was conducted, Ginsburg's revision of this genus had not yet appeared. Specimens were collected and field identifications were not attempted except to note specimens with unusual color patterns. This has enabled me to separate *S. diomedianus* by my field notes, but *S. civitatum* and *S. plagiusa* have no distinguishing color differences and they are grouped together in the fishing log. Therefore, this discussion is based on the collection in the Institute of Marine Science.

The few fish listed in the fishing log are not indicative of the abundance of the tongue sole. It was almost ubiquitous in the trynet, but it rarely appeared in the big net, except when it became entangled in the meshes.

My collection contains the following specimens of *S. civitatum:*

3 from 17–19½ fms. off St. Joseph Island, Dec. 1950
11 from 11 fms. east of Freeport, Texas, May 11, 1951
8 from 18–23 fms. off Padre Island, May 13, 1951
2 from 6½ fms. off edge of Sabine Bank, June 15, 1951
1 from 19–23 fms. off Grand Isle, June 28, 1951
7 from 12–18 fms. off Padre Island, July 6–11, 1951
16 from 14–20 fms. off Obregon, July 29–Aug. 6, 1951

The distribution of my specimens is not much different from that given by Ginsburg (1951). This is a shallow water species, probably most common in depths of 10–30 fathoms, and it was not taken in depths of 30–40 fathoms on the 24–10 grounds.

Symphurus diomedianus (Goode and Bean)

Only three specimens of this distinctive little tongue sole were obtained, one in 18 fathoms off Greens Bayou on December 18, 1950, one in 18 fathoms off Corpus Christi

Pass on January 4, 1951 and one in 14–20 fathoms off Obregon, Mexico. The rarity of this species on mud bottom might indicate that the few specimens captured are strays from hard bottom such as snapper banks.

Symphurus plagiusa (Linneaus)

Ginsburg (1945) found that this was the common species in the bays and shallow water of the Texas coast, and he showed that this species was common only in bay areas of relatively high salinity. Apparently, there is an offshore movement during the winter and one specimen was obtained in 17–19½ fathoms off St. Joseph Island during December, 1950. Four others were obtained in 7 fathoms along the edge of Sabine Bank during June. This species was sometimes taken in the same drag with *S. civitatum.*

Approximately 510 tongue soles were taken in the large net, and probably 95 per cent of these were *S. civitatum.*

Symphurus pelicanus Ginsburg

Three small specimens, 60–67 mm., were caught in 30–37 fathoms off 24° 10′ N. According to Ginsburg (1951) this species occurs on mud bottom in slightly deeper water than *S. civitatum.*

Lophobranchii

Syngnathidae

Syngnathus louisianae Günther

Pipefishes are usually found in areas of cover, either algae or higher plants. On the Texas coast there are two species, *S. scovelli* and *S. floridae,* which predominantly occur on *Halodule* and *Thalassia* flats. There are other pipefishes which occur pelagically among the sargassum weed, but no pelagic species have as yet been recorded from Texas. Shrimp trawls are not suitable gear for catching pipefishes.

Eleven specimens of pipefishes were caught, 2 in 6½ fathoms on the edge of Sabine Bank, 8 in 12–18 fathoms off Padre Island during July, and 1 specimen in 17 fathoms off Obregon. The July specimens were large, (254–308 mm. long) and the males had the brood pouches filled with eggs.

Hippocampus hudsonius hudsonius DeKay

Three seahorses were caught, 1 in 18–21 fathoms east of Port Aransas and the other two in 6½ fathoms around Southwest Bouy off Sabine Pass. These specimens were entangled with sargassum in the webbing of the net and were undoubtedly caught near the surface.

Aulostomi

Fistulariidae

Fistularia tabacaria Linnaeus

Fifty-six coronet fish were caught, 55 off Obregon, Mexico, and 1 in 18–20 fathoms off Padre Island during May, 1951. The Obregon specimens ranged in size from 252–

670 mm., and the single specimen caught in Texas waters measured 400 mm. This is a rare species on the Texas coast.

Percomorphii

Sphyraenidae

Sphyraena guachancho Cuvier and Valenciennes

Most of the records of this small barracuda are from the southern part of the Texas coast. Very small juveniles are sometimes caught during the late fall, and often they are donated to the laboratory. One barracuda 119 mm. long, was captured in 5 fathoms of water off Pass Cavallo on October 24, 1951.

Ninety-eight adults were counted, 10 in 12–18 fathoms off Padre Island during July and eighty-seven off Obregon in 14–20 fathoms between July 29 and August 6, 1951.

Three females, 264, 254, and 287 mm. long, which were caught during July off Padre Island, had enlarged ovaries and appeared ready to spawn. Several specimens examined off Obregon, Mexico, during August had spent ovaries.

Polynemidae

Polydactylus octonemus (Girard)

The threadfin is one of the most abundant fish along the Texas coast. Gunter (1945) found this species common inside the 10 fathoms contour except during the winter months. At what depth this species winters is still unknown.

Twenty-six thousand four hundred and forty fish were counted on the Texas grounds, 592 on the Obregon grounds and 25,800 off Sabine, Texas. A few fish, 30 in all, were taken during November in depths of 17–20 fathoms, off Padre Island. Threadfins were not caught during January and December off the Texas coast although they were common in 6–10 fathoms off Campeche during February, 1951. Threadfins, ranging in length from 115–157 mm., were caught off Padre Island in 12–15 fathoms during July. Off Obregon, large fish were caught during July and August, 1951.

The capture of large numbers of threadfins, 90–128 mm. in 3–6 fathoms off Sabine, Texas, was not unexpected (See Gunter, 1945). However, it should be noted that the Sabine trawling was done entirely in daylight, while most of the brown shrimp trawling is at night.

Gunter (1945) has described the feeding of this species along the bottom where it uses the pectoral rays as a funnel or push net. When the writer was in Freeport, Texas, many threadfins were seen feeding alongside docked ships. The free pectoral rays would be extended forward as a scoop and they would swim to and fro alongside the boat just a few inches below the surface of the water. They appeared to be funneling small organisms from the fouling algae and hydroids into their mouths. At no time were the extended pectoral rays actually observed in contact with the boat.

Scombridae

Scomber colias Gmelin

The chub mackerel has not been reported previously from the western Gulf, and the only published record of its occurrence in the Gulf is at Garden Key in the Tortugas

Islands (Rivas, 1951). Six chub mackerel were taken off Padre Island in 17–22 fathoms of water during May. In July nine more mackerel were caught in nearly the same locality in 15 fathoms. This area off Padre Island is an interesting locality; as previously stated, it is an area of convergence. The chub mackerel were all small, 151–161 mm. Herman Hayes, a shrimp fisherman, brought a chub mackerel into the laboratory 245 mm. long, which was caught in 33–49 fathoms off Mustang Island during April, 1954. The ovaries appeared to be nearly ripe.

Cybiidae

Scomboromorus maculatus (Mitchill)

Shrimp trawls are not suitable gear for capturing this pelagic fish. Spanish mackerel are highly prized by the sports fishermen, but no commercial fishery exists in Texas waters.

Forty-two Spanish mackerel were caught, and this small figure illustrates the infrequent capture of this species. Of course, more would be taken if the trawl happened to pass through a large school. Eight specimens were captured during October in 3–15 fathoms of water, and the smallest fish caught was 94 mm. and the largest was 246 mm. Gunter (1945) has shown that this mackerel is present in winter and my data confirm the fact also, but nevertheless, the main population of mackerel may migrate south. During December and January, 30 mackerel were caught in 17–25 fathoms off St. Joseph and Padre Islands. In addition one mackerel was caught in 10 fathoms on December 11, 1950, off St. Joseph Island. One Spanish mackerel was caught off 24° 10′ N. in 32–37 fathoms of water on March 7, 1951.

Trichiuridae

Trichiurus lepturus Linnaeus

Cutlass fish are one of the most abundant fish on the white shrimp grounds (Gunter 1936, 1945). This fish is called the silver eel by Texas fishermen, and it is sometimes taken in enormous numbers. According to Gunter (1945) this species is found in the bays and the shallow Gulf throughout the year.

Approximately 44,135 silver eels were counted, 33,000 off Sabine, Texas, 4,000 on the Southwest Pass grounds, 3,000 on the Texas grounds, 257 on the 24–10 grounds and 3,870 on the Obregon grounds.

A cursory inspection of my fishing log shows the tremendous abundance of silver eels off Sabine, and the high catch per hour of trawling. Silver eels became so entangled with the numerous small croakers that sorting the catch was difficult and very tedious. Silver eels together with croakers were so abundant off Sabine during June, 1951, that the fishermen had either to reduce their trawling time by half or seek different grounds.

Many drags contained a few silver eels, but nowhere except at Sabine were they observed to be abundant. This species probably winters close to shore as the greatest winter abundance was found in 10 fathoms off Pass Cavallo on December 11, 1950. Nevertheless, silver eels were found throughout the depths fished, and it was not rare on the 24–10 grounds. The June and July catches seem to indicate that the largest summer concentration of this fish is inshore in water of less than 12 fathoms.

No measurements were made of this fish, except a notation on the abundance of the small silver eels entrapped in the meshes of the trawl in 17 fathoms off Obregon on July 31, 1951.

Stromateidae

Peprilus paru (Linnaeus)

Springer (1952) found this species quite common in midwater trawls off Mississippi. Consequently, small catches of this species in shrimp trawls are more indicative of the selection of the gear used, rather than of abundance.

One hundred and twenty-one harvest fish were counted, 83 on Texas grounds, 26 off Sabine, 7 on the 24–10 grounds, 1 on the Southwest Pass grounds, and 4 off Obregon. The number caught is so small that few conclusions can be drawn regarding its distribution. It was caught during all months of the year, and throughout the bathymetric distribution of drags.

Poronotus triacanthus (Peck)

Young butterfish are often taken during the spring from the bell of *Stomolophus meleagris*, where they seek refuge. Gunter (1945) found this species more common in Louisiana in shallow water than in Texas.

Forty-two thousand butterfish were counted, 39,870 on the Texas grounds, 187 on the 20–10 grounds, 550 on the Southwest Pass grounds, 1,360 on the Sabine Pass grounds, and 166 off Obregon.

Butterfish were taken throughout the year, but young specimens 90–105 mm. long appeared in enormous abundance during May. It was the most abundant fish in many of the drags, and in several it amounted to more than 95 per cent of the catch by weight. This abundance was also observed during July.

During the winter, catches of butterfish were rather sporadic and it was never found in great abundance. Springer (1952) reported captures of large numbers of this species in a midwater trawl which would indicate a pelagic existence. Like the squid, *L. pealei*, more butterfish were caught during the early morning and daytime drags than at night during May, and during July the two largest drags were made during the daytime. The largest butterfish measured only 173 mm. long and it was caught in 12–13 fathoms off Wine Island Pass.

Carangidae

Seriola dumerili (Risso)

Amberjacks are common on the snapper banks and I identified three amberjacks which were caught at Aransas Reef in 37 fathoms of water off Port Aransas during September, 1951. A single specimen, 159 mm. standard length, was taken in 16–18 fathoms off Padre Island on July 7, 1951.

Trachinotus carolinus (Linnaeus)

Small pompanos are very common in the surf on Mustang Island during the summer months as noted by Gunter (1945). According to the statistics of the Texas Game

and Fish Commission, a few pounds of pompano are landed during every month of the year. The total catch for the fiscal year 1951–52 was 5,388 pounds. The records show the greatest catches in March and November, but the poundage is so low that this catch may be more indicative of the fishing effort than of seasonal abundance of pompano. This species is apparently more common south of the Rio Grande, where the writer saw about 100 fish in a single haul of an 800 foot beach seine on August 31, 1951. Pompanos are imported into Brownsville, Texas, from Mexico.

Only two pompanos were caught, one 278 mm. long, in 18 fathoms off St. Joseph Island on December 9, 1950, and the other 222 mm. long in 20–22 fathoms off Corpus Christi Pass on January 23, 1951.

Selar crumenopthalmus (Bloch)

A single specimen was taken in 22 fathoms off Pass Cavallo. This is apparently the first record for Texas although two specimens have been recorded from Louisiana (see Ginsburg, 1952).

Trachurus lathami Nichols

The rough scad is a pelagic species and the gear used was inadequate for its capture. Ginsburg (1952) says that the "Pelican" obtained 30 specimens in the area from Carrabelle, Florida, to the Rio Grande in 7–45 fathoms. Gunter (1945) reports 29 specimens caught in the Gulf off Port Aransas, Texas.

Four hundred and forty-one rough scad were counted, 410 on the Texas grounds, 25 on the Southwest Pass grounds, 2 on the 24–10 grounds and 4 on the Obregon grounds. This species is common on the Texas coast only during the summer months. Although my data are very inconclusive, it appears that this species like the squid, *L. pealei*, and the butterfish, *P. triacanthus*, is caught most often during the early morning and daylight drags. All specimens caught were small and few exceeded 120 mm.

Next to the moonfish, *Vomer setapinnis*, this was the most abundant carangid in the trawls. According to Herman Hayes, the rough scad was one of the most abundant fishes on the Lobos Island ground during March, 1954.

Hemicaranx amblyrhynchus (Cuvier and Valenciennes)

The young of this species is often found under the bell of the cabbage head, *Stomolophus meleagris*, during the fall and winter. Three small specimens were caught in 3–6 fathoms off Greens Bayou; several others were taken in trynets.

Caranx hippos (Linnaeus)

Jackfish are caught by the sportsmen at Port Aransas throughout the summer. The young of this species live in the shallow water along the Texas coast. Jackfish were caught most often during October when they were recorded from 10 drags, in 3–15 fathoms. Two were caught during November and one, 135 mm. long, was caught in 10 fathoms off Pass Cavallo during December, 1950.

Chloroscombrus chrysurus (Linnaeus)

Gunter (1945) found this species during the summer and fall in the shallow water along the Texas coast. The writer found that the bumper was very abundant on the Campeche Bank in 6–10 fathoms during February, 1951.

Approximately 600 bumpers were counted, 118 on the Texas grounds, 199 on the 24–10 grounds and 280 on the white shrimp grounds off Sabine. This little carangid was not caught during December and January in 17–25 fathoms off St. Joseph and Mustang Islands. A few bumpers were caught during March in 37 fathoms on the 24–10 grounds. The largest specimen, 195 mm. long, was caught on the 24–10 grounds. Evidently this species moves in close to shore during the summer as none were caught in 12–13 fathoms off Padre Island during July.

Vomer setapinnis (Mitchill)

Gunter (1945) found that this species was the most common carangid in shrimp trawls. The moonfish is a very compressed deep bodied fish and the adults cannot escape through the meshes of a shrimp trawl. Possibly, it feeds at or near the bottom, but little information is available on its life history.

Approximately 2,976 moonfish were counted, 1,020 on the Texas grounds, 930 on the Southwest Pass grounds, 26 on the 24–10 grounds, 470 on the Obregon grounds and 530 on the Sabine grounds. This species appears to be most abundant in east Texas and Louisiana on the basis of the very limited trawling in that area. This has previously been noted by Gunter (1945). Moonfish were caught at all depths fished, but they were most common in the shallow water of less than 15 fathoms during the summer months.

Little information was gathered on this species. Moonfish, ranging in size from 110 to 171 mm., were caught on the 24–10 grounds during March. During July moonfish, ranging in length from 121–165 mm., were common, and one small specimen about 40 mm. long was captured. The 165 mm. moonfish caught during July was a female and it had nearly ripe gonads.

Selene vomer (Linnaeus)

The look-down was taken in only three drags during the course of this investigation. These drags were completed in 17–19 fathoms off Padre Island a few miles north of Sebree Bank during November. The smallest look-down was 72 mm. and the largest was 111 mm. This species is not as common as *V. setapinnis* on the Texas coast. Gunter (1945) caught it slightly more often in shallow water than I did in deeper water.

Pomatomidae

Pomatomus saltatrix (Linnaeus)

Bluefish have not been common anywhere on the Texas coast during recent years. At one time this fish supported a small fishery at Galveston and Sabine, Texas. Fishermen at Sabine blame the menhaden fishermen for the decline of this species. However, the decline actually occurred when there were no reduction plants in this area. Miles and Simmons (1950) have shown that bluefish are rarely taken in menhaden nets on

the Louisiana coast. Evidently this species has always been rare off Port Aransas, although occasionally a number are taken from the fishing piers.

Only 13 bluefish were caught during this investigation. A bluefish 309 mm. long was caught in 18 fathoms off St. Joseph Island on December 11, 1950. The remaining bluefish, ranging in length from 208–218 mm., were caught in 6–7 fathoms off Sabine, Texas.

Rachycentridae

Rachycentron canadus (Linnaeus)

A number of ling are caught by sports fishermen in the northern Gulf. Most of them are caught from small boats in the open Gulf but occasionally a few are caught off the jetties along the Texas coast. During late March, 1953 several dozen ling were caught off the Port Aransas jetties and fishing piers. Ling are rarely caught in shrimp trawls. Small specimens under two feet long were seen by the writer in shrimp trawls off Campeche, Mexico.

Only three ling were caught during this investigation. One was caught in 21–31 fathoms on the 24–10 grounds on March 6, 1951; another was taken on March 14 in 24 fathoms of water north northeast of Brazos Santiago. The final specimen, 2½ feet long, was found entangled in the head rope of the trawl. This ling was caught in 17–19 fathoms off Obregon.

During the summer months ling collect around anchored boats in the Gulf. The writer has often seen 3 to 5 ling swimming around his shrimp boat. Often he has caught these ling by dropping a baited hook overboard. Shrimp or squid are usually the best bait. As there is not a steady market for ling along the Texas coast, and as ice is sometimes in short supply, ling caught by shrimpers are not always marketed.

Serranidae

Epinephelus niveatus (Cuvier and Valenciennes)

Groupers are usually caught on hook and line along the Gulf coast. They prefer coral reefs, wrecks or other debris that affords hiding places. It is only the rare stray that is caught in a shrimp trawl. A single snowy grouper 105 mm. long was caught in a trynet in 19 fathoms off Obregon, Mexico, on August 1, 1951.

Garrupa nigrita (Holbrook)

Only three specimens of the black grouper were caught. Two black groupers, 157 and 217 mm. long, were caught in 15 fathoms off St. Joseph and Matagorda Islands during October, 1951. A small specimen 84 mm. long was taken in 15–16 fathoms off Obregon, Mexico, on August 4, 1951.

Promicrops itaiara (Lichtenstein)

The spotted jewfish are caught along the Port Aransas and the Port Isabel jetties during the spring, summer and fall months. Usually the first jewfish of the year is caught off Port Isabel jetties during early March and it is normally April before one is caught off Port Aransas jetties.

A total of four jewfish was landed during this investigation. The fifth specimen which was caught in 17 fathoms off Padre Island escaped through a hole in the net as it was being raised to the surface of the water. Four specimens, ranging in length from 6 to 6½ feet, were caught on the Obregon grounds during August. Although jewfish were in demand in Aransas Pass, ice could not be spared to preserve these fish, as it was needed for the more valuable shrimp.

Diplectrum formosum (Linnaeus)

No numerical data are available on this species on the Texas coast. Gunter (1941) reports it as not uncommon on the snapper banks. Baughman (1950) says that there are museum specimens from Freeport and Galveston, Texas. I have not collected nor seen Texas specimens. It is very common in 6–10 fathoms off Campeche, Mexico.

The sandfish is included in this report on the basis of three adult fish caught in 19–20 fathoms off Obregon, Mexico.

Diplectrum arcuarium Ginsburg

Ginsburg (1948) summarized the collection of the "Pelican" in regard to this species. He found this *Diplectrum* in the region from Port Isabel, Texas, to Pensacola, Florida, in 8–35 fathoms of water.

Five thousand five hundred and ninety sandfish were counted, 4,350 on the Texas grounds, 1,160 on the Obregon grounds, and 85 on the 24–10 grounds. One specimen was taken in a trynet in 10 fathoms of water off Port Aransas during October. This was the shallowest depth of capture. It was rather rare in depths of 31–37 fathoms on the 24–10 grounds. It is, therefore, probable that it is most abundant in the 15–30 fathom zone.

A few measurements were taken. The smallest specimens, 24–40 mm., were taken during July on the Texas grounds and during July and August off Obregon. The largest specimen was 150 mm. long and it was captured off Obregon. This is one of the three lesser serranids which are so abundant on the brown shrimp grounds. Sandfish apparently live within a much narrower depth range than the other two common small serranids on the brown shrimp grounds. *D. arcuarium* seems to be more common on mud bottom in contrast to *D. formosum*.

Centropristes philadelphicus (Linnaeus)

This is the common sea bass of the brown shrimp grounds, and it is the only species of *Centropristes* definitely recorded from Texas. *C. melanus* may be found on the shallow water snapper banks on the Texas coast, but no specimens are now available.

Seven thousand one hundred and sixty sea bass were counted, 4,087 on the Texas grounds, 2,075 on the Southwest Pass grounds, 805 on the 24–10 grounds, and 190 on the white shrimp grounds off Sabine. This species was taken in all depths trawled, but it was most common off Louisiana in 19–23 fathoms. Nothing in the known habits of this species would account for its complete absence at Obregon, where a special search was made for this species, but none were seen.

Sea bass, ranging in length from 154 to 279 mm., were caught during the winter months. Small specimens 68 mm. in length were first taken during May, and only small seabass, ranging in length from 53–70 mm., were caught in 3–7 fathoms off Sabine, Texas.

Paracentropristes pomospilus Ginsburg

The type locality of this little serranid is 26 fathoms off St. Joseph Island. Ginsburg (1952) gives the bathymetric range as 20–90 fathoms.

This is certainly one of the most abundant fish on the brown shrimp grounds. Large numbers escape through the meshes of the trawl, and they are often seen floating away from the net as it is lifted into the boat.

Twenty-six thousand seven hundred *P. pomospilus* were caught, 5,100 on the Texas grounds, 20,000 on the Obregon grounds, 1,370 on the 20–10 grounds, and 200 on the Southwest Pass grounds. This species was caught in depths of 12 to 42 fathoms during this investigation.

The largest specimens (94–100 mm. long) were caught in the deepest water. The average size of 38 specimens caught in 17–20 fathoms during November was 71 mm. standard length, and the range was 64–79 mm. The small specimen, 49 mm. long, was caught during December in 18 fathoms south of Greens Bayou. Other small specimens about 35 mm. were caught during March in 31–37 fathoms and during January in 24 fathoms. This would indicate a long breeding season.

Serraniculus pumilio Ginsburg

This small serranid was recently described by Ginsburg (1952). He had examined 21 specimens from the northern Gulf coast; and the bathymetric range of these fish was 8 to 35 fathoms. He further states that this is the smallest of the American serranids and that it is probably hermaphroditic.

I caught a single speciman 67 mm. long in 15 fathoms off Padre Island on July 8, 1951. Nothing is known of the habits of this small serranid, but the locality of capture suggests that it may be a stray from the snapper banks.

Priacanthidae

Priacanthus arenatus Cuvier and Valenciennes

A few specimens have been recorded from the Texas coast from time to time, but it is not a common fish. Twelve big-eyes were caught, 4 in 15–21 fathoms off Padre Island, and 8 off Obregon. The Obregon specimens ranged in length from 93–97 mm. The largest specimens, ranging in length from 225 to 310 mm., were caught during November off Padre Island in 17–19 fathoms.

Lutianidae

Lutianus blackfordi Goode and Bean

One of the oldest fisheries in the Gulf of Mexico is based on the red snapper. In Texas the snapper fleet is concentrated chiefly in Galveston, Port Arthur, and Freeport. There is some commercial snapper fishing from Port Isabel, and sporadically at Aransas Pass. Except for the menhaden, which is used for reduction purposes, the snapper fishery is the only offshore food fish (Pisces) regularly fished.

Very little information has accumulated on the red snapper and it has not been the subject of an intensive investigation anywhere in the Gulf of Mexico. Usually when large red snappers are caught in a trawl, extensive net repairs are necessary, as the

snappers stay close to obstructions. Small red snappers are not uncommon in shrimp trawls, but rarely are they encountered in abundance.

Four hundred and sixty red snappers were counted, 151 on the Texas grounds, 26 on the Louisiana grounds, 254 on the Obregon grounds, and 280 on the 24–10 grounds. Most of the Obregon catch (200 snappers) was taken in a single drag in 19 fathoms of water. At least part of this drag was made on shell bottom, and it was, probably fortunate that the drag was stopped when it was, or extensive repairs would have been necessary. The largest red snapper was 700 mm. long and the smallest was 51 mm. As very little information is available on small red snappers, a few measurements are given below:

October; "San Jacinto"; 3 snappers; 71–93 mm.
November; "Rio Bravo"; 5 snappers; 51, 74, 240, 240, 365 mm.
December; "Gypsy Girl"; 12 snappers; 54–121 mm.
December; "Dr. Billy"; 3 snappers; 82, 108, 150 mm.
January; "Sabine No. 1"; 4 snappers; 90, 100, 123, 126 mm.
January; "Gypsy Girl"; 1 snapper; 172 mm.
March; "Capt. Geo. Hamilton"; 6 snappers; 99, 101, 109, 114, 600, 700 mm.
April; "40 Fathoms No. 34"; 2 snappers; 115, 214 mm.
May; "Capt. Geo. Hamilton"; 2 snappers; 270, 700 mm.
June; "Mister Mac"; 14 snappers; range 160–245 mm. (700 mm.)
July; "Capt. Geo. Hamilton"; 9 snappers; 106, 123, 133, 134, 152, 155, 149, 163 mm.
August; "Texas Clipper"; 8 snappers; 154, 156, 165, 175, 188, 239, 247, 272 mm.

Lutianus synagris (Linnaeus)

Lane snappers are rarely caught in shrimp trawls, and evidently they are too small to be of commercial importance on the snapper banks. Twenty-eight Lane snappers were caught, 17 on the Texas grounds, 6 on the Southwest Pass grounds, and 5 on the Obregon grounds. The largest was 255 mm. long and the smallest was 22 mm. The following measurements are given by months: October 52–68 mm.; November 100 mm.; December 89–114 mm.; January 100–123 mm.; June 155, 220, 245 mm.; August 22–170 mm. (6 snappers).

Lutianus analis (Cuvier and Valenciennes)

One muttonfish 180 mm. long was caught in 19 fathoms off Obregon.

Lutianus griseus (Linnaeus)

A single specimen of the gray snapper was caught in 17 fathoms off Obregon, Mexico. This is a common resident species along the jetties at Port Aransas, Texas.

Pristipomoides andersoni Ginsburg

This common snapper, like some other species on the Texas coast, has been only recently described. The type locality is off Padre Island in 90 fathoms. Ginsburg (1952) gives a bathymetric range for this species of 13–95 fathoms. Therefore, the major part of its range is outside the depths now trawled by the shrimp fishermen.

Seventy-six specimens were caught, 47 on the Texas grounds, 14 on the Obregon grounds, and 15 on the 24–10 grounds. All specimens were caught between 15 and 37

fathoms. No particular seasonal movement is discernible in my data. Nearly all specimens are small. The largest was 89 mm. and the smallest was 49 mm. The smallest specimen was caught south of Greens Bayou in 24 fathoms on December 18, 1950.

Rhomboplites aurorubens (Cuvier and Valenciennes)

This species is probably confined more to the snapper banks than the preceding species. A single specimen 173 mm. long was caught in 16–17 fathoms off Padre Island during July.

Haemulidae

Bathystoma aurolineatum rimator (Jordan and Swain)

According to Baughman (1950) eight specimens which were caught at Heald Bank during March, 1950, are the only records from Texas. There would be little reason to discuss this rare species further as only one specimen was caught during this investigation except for the fact that this grunt was the most abundant species on the pink shrimp grounds off Campeche, Mexico. The predominance of this grunt off Campeche is one of the major differences between the fish fauna of the northwestern and southern Gulf. Reid (1954) took only four specimens at Cedar Keys, Florida during his investigation although Jordan and Evermann (1898: 1309) state that the young of this species swarm about the wharves and shores near Pensacola, Florida. Buller (1951) lists this grunt as the most abundant species in one trawl haul made in 19 fathoms off South Carolina.

My specimen was taken in 21 fathoms off Padre Island on May 14, 1951. There is a possibility that this species will be found in some abundance on the shell ridge off Galveston and Sabine, Texas.

Conodon nobilis (Linnaeus)

This species is occasionally caught by the tourist anglers on South Pier at Port Aransas, Texas, during the spring and summer. I have seen as many as 30 barred grunts on the pier at one time. They were all too small to be of interest to the pan angler. This species is apparently more common along the coast of Tamaulipas, and large specimens that were imported from Mexico were seen in Brownsville. I also examined several caught in a beach seine about 70 miles below the Rio Grande on August 31, 1951. According to Gunter (1945) at Port Aransas it is near the northern part of its range on this coast.

Several small specimens were caught in trynets in three to four fathoms off Mustang Island on October 21, 1950. Five more were caught in 16–19 fathoms off Obregon, Mexico.

Orthopristis chrysopterus (Linnaeus)

According to Ginsburg (1952) the pigfish is a temperate rather than a tropical water fish and he found it in reduced abundance around the Florida Keys. However, the only place that I found this species very abundant was on the shell banks off Campeche, Mexico, a tropical area. This applies only to trawl catches. Young pigfish are taken in large numbers by pushnetting over grass flats in Texas bays and according to Reid

(1954) large catches are also made on the grass flats at Cedar Key. A few specimens were taken in 3–15 fathoms off the central Texas coast during October, but it was not abundant.

Sparidae

Stenotomus caprinus Bean

Gunter and Knapp (1951) have summarized the status of this species along the Texas coast. It is certainly one of the most common species on the brown shrimp ground, particularly during the winter season.

Approximately 10,370 porgies were counted, 7,940 on the Texas grounds, 1,909 on the 24–10 grounds, 410 on the Obregon grounds, and 6 on the Southwest Pass grounds. Several peculiarities were noted in the distribution of this species. It was much more common during the winter than during the summer months. In part this may be due to the landward shift of the shrimp fishery during the summer months. Another peculiarity noted was that this species was very abundant in 18–22 fathoms at the northern end of the Texas ground while it was very rare or absent at the southern end during May, 1951. During February, 1954, I took 14,200 scup during 19 hours of trawling in 25–26 fathoms off Mustang Island and it was the most abundant species taken.

There was a definite size relationship with depth and season. The size range was 98 to 115 mm. in 17–25 fathoms off the Texas coast during the winter, while specimens as large as 158 mm. were taken in 37 fathoms on the 24–10 grounds. The fish taken during February, 1954, ranged in size from 106–159 mm. total length. The gonads were well developed, which indicates that the species spawns in the spring of the year. Most of the porgies caught during June, July and August were small. Few exceeded 60 mm.

Lagodon rhomboides (Linnaeus)

Pinfish are very abundant and they are well known to all coastal anglers. Two hundred and thirty-two pinfish were counted, 39 on the Texas grounds and 193 on the 24–10 grounds. It was surprising to find this species in 40 fathoms on the 24–10 grounds, although it is possible that only strays from the nearby rock were caught. Only adults were caught during this investigation, although young pinfish are very abundant on the grass flats in all Texas bays.

Family Gerridae

Eucinostomus gula (Cuvier and Valenciennes)

The taxonomic status of the mojarras is confused and the species are difficult to separate in the field. All field data are grouped under the genus name, but as an adequate collection was made, it has been possible to determine the species encountered.

E. gula was the most common species and it is estimated that at least 95 per cent of *Eucinostomus* caught belonged to this species.

One thousand two hundred and sixty mojarras were caught, 280 on the Texas grounds, 179 on the 24–10 grounds, 225 on the Southwest Pass grounds, and 580 on the Obregon grounds.

E. gula, ranging from 79–105 mm. in length, were taken in 37 fathoms on the 24–10 grounds. Size varied very little from locality to locality.

Eucinostomus argenteus Baird and Girard

This was a rare species on the brown shrimp grounds, but it is probable that this species is more common over shell sand. Thirteen silver mojarras are in the collection. All these specimens were caught off Padre Island, Mustang Island area, or on the 24–10 grounds. The bathymetric distribution is 3 to 37 fathoms. Small specimens 94–113 mm. long were taken in the trynet in three fathoms off Mustang Island during October.

Diapterus rhombeus (Cuvier and Valenciennes)

Twenty specimens of this mojarra were taken from a "shell pile" in 19 fathoms off Obregon, Mexico. No additional specimens were seen during extensive trawling on the mud bottom off Obregon. This species is not uncommon on Campeche Bank.

Mullidae

Upeneus parvus Poey

Goatfish are not uncommon along the Texas coast, particularly during the summer months. Three hundred and fifty-three goatfish were counted, 210 on the Texas grounds, 65 on the 24–10 grounds, 56 on the Obregon grounds and 14 on the Southwest Pass grounds. The gear used was not suitable for catching this slender fish. However, a number of small specimens 75 mm. long were caught during July. Two size classes were also noted during March when the larger class ranged from 134–154 mm. and the smaller ranged from 69–73 mm. Lachner (1954) says this species seems to be rare, but that only applies to museum specimens.

Sciaenidae

Larimus fasciatus Holbrook

Gunter (1945) found the banded croaker more common in Louisiana than in Texas. I found the same situation. Eight hundred and eighty-four banded croakers were counted, 199 on the Texas grounds, 545 on the Southwest Pass grounds, 130 on the white shrimp grounds off Sabine, 5 on the 24–10 grounds and 5 on the Obregon grounds. Banded croakers were taken between the depths of 3 and 32 fathoms. The largest specimen measured 208 mm. It was taken off Grand Isle, Louisiana. Two small specimens 40 mm. long were taken in 3–4 fathoms off Mustang Island on October 21, 1950.

Stellifer lanceolatus (Holbrook)

Star drum are rare on the brown shrimp grounds. Several were caught during October in 12 to 15 fathoms off the central Texas coast. It was fairly common in the shallow water along the Gulf coast during October. Thirty-two hundred fish were counted on the white shrimp grounds, off Sabine during June, 1951.

Leiostomus xanthurus Lacépède

The spot is not an important food fish on the Texas coast for it does not reach a large size (See Gunter, 1945). A few are occasionally landed by shrimp trawlers.

One thousand one hundred and forty spots were counted, 320 on the Texas grounds, 700 on the Southwest Pass grounds, 1 on the 20–10 grounds, and 125 on the white shrimp grounds off Sabine. Spots were more common in the deep water during the winter, although only 1 was taken during March in 21–37 fathoms on the 24–10 grounds. The complete absence of this species off Obregon during July and August can be best explained by an inshore summer migration.

None of the fish caught during this investigation were large. A few were good pan-sized fish and they were eaten aboard the shrimp boats. Only a few measurements were taken. The spots caught in Louisiana ranged in size from 175–185 mm. while those caught off Sabine ranged from 130–160 mm. The largest specimen measured 210 mm. and it was taken in 24 fathoms off Padre Island during January.

Micropogon undulatus (Linnaeus)

Both Pearson (1929) and Gunter (1945) have commented on the extreme abundance of the croaker along the Texas coast. Gunter found that the croaker was most abundant during the summer and least abundant during the winter in the bays and shallow waters.

Sixty-nine thousand croakers were counted, 2,800 on the Texas grounds, 28 on the 24–10 grounds, 311 on the Obregon grounds, 7,400 on the Southwest Pass grounds and 58,500 on the white shrimp grounds off Sabine, Texas. The croaker was taken everywhere that trawling was done and in all depths.

At no time were the croakers really abundant on the offshore brown shrimp grounds, although they were more common in winter. Perhaps the small catches of croakers on the brown shrimp grounds can be attributed to night trawling. None of my data directly bears on this question, unless one so interprets the catch during May, as the few croakers, 20 in all, were caught during daylight or in the early morning drag. In the spring croakers became rare on the offshore grounds, while in the fall they increase in number. Croakers were noted as the most abundant fish in several drags that were completed in 15 fathoms during October, 1950.

Shrimp fishermen complained of the great number of croakers in Louisiana during 1950. Croakers were so abundant that trawling time had to be cut in half or the net would burst from the weight of the croakers. Fishermen stated that they did not put over the big net if more than one croaker was seen in the trynet. Fishermen did not like the slow and tedious task of sorting the few shrimp from the enormous mass of croakers. It is interesting to note that this supposed big increase in croakers followed a sharp decline in the abundance of white shrimp.

Croakers were extremely abundant off Sabine during June. Fishermen stated that it was their opinion that they were much more abundant than usual, but as they never marketed croakers, it was difficult to state this abundance in quantitative terms. Nevertheless, the abundance of croakers was so great and the catch of shrimp so low that few boats were operating. The size of the population is shown by the capture of 6,500 croakers in an hour of trawling with a 100 foot net. Most boats were operating without full crews, and if the trash fish had not been so abundant, more time could have been spent fishing. As it was the crew could not sort one trawl fast enough so that they could take care of the next drag without delay.

Very few size measurements of croakers were made. However, the Sabine specimens ranged in length from 130–160 mm., and according to Pearson these croakers would

be almost a year old. Winter caught fish were all larger, but many of the bigger croakers probably avoided the net. Off the Texas coast, the size range was 179 to 268 mm. long. On the Southwest Pass grounds the range was 209 to 230 mm. During July off Padre Island most of the croakers were small, and the mode was around 150 mm. Several croakers were taken off Obregon, Mexico, during August that measured 200 to 210 mm. One 210 mm. individual was noted as having nearly ripe gonads.

Five croakers examined off Sabine were found to be feeding entirely on polychaete worms. Several specimens were caught at night in 17–24 fathoms off Corpus Christi Pass and examined, but no food was found in the stomach.

Umbrina coroides (Cuvier and Valenciennes)

This sciaenid resembles *Menticirrhus* in that a single barbel is present on the chin. In coloration it most closely resembles the barred grunt, *Conodon nobilis*. Five specimens were caught in 19 fathoms off Obregon. At least a part of this drag was completed over a "shell pile" and as it was not taken elsewhere on the Obregon grounds, presumably it prefers a shell bottom. Little is known of its distribution in the Gulf, but it has not been recorded from the northern part. One specimen measured 206 mm.

Menticirrhus focaliger Ginsburg

This species is reported from the Texas coast for the first time. Very little is known of its abundance. It is discussed in detail because Ginsburg (1952) has used this species to illustrate the faunal difference between the eastern and western Gulf. Ginsburg had no record of its occurrence in the western Gulf.

Only two specimens were noted during this investigation. These were caught in 3–4 fathoms off Matagorda Peninsula on October 23, 1951. I have seen another in a fish house in Aransas Pass. The fish buyer told me that he got a number of fish like that, but that he had supposed that it was a color phase of the common whiting, *Menticirrhus americanus*. It is also taken by tourist anglers at Port Aransas. However, it does not appear to be common, and Doctor Gunter has informed me that he had never seen this species on the Texas coast prior to October, 1950. This species is not uncommon on Campeche Bank and several were seen during February, 1951.

Menticirrhus americanus (Linnaeus)

This is the common whiting along the Texas coast. There is no steady demand for this species at Aransas Pass, Texas, and shrimp trawlers save this fish for market only upon the request of fish buyers.

Two thousand three hundred and eighty whiting were counted, 1,194 on the Texas grounds, 438 on the 24–10 grounds, 195 on the Southwest Pass grounds, 130 on the Obregon grounds, and 430 on the white shrimp grounds off Sabine.

Whiting were taken everywhere that trawling was done and at all depths. This species was more common than the croaker in 31–37 fathoms on the 24–10 grounds. There is an offshore movement during the winter and an onshore one during the spring, as was previously noted by Gunter (1945).

Most of the whiting caught offshore were large. Winter specimens ranged in length from 216 to 320 mm. All whiting caught during July off the Texas coast in 12–18 fathoms and off Obregon in 14–20 fathoms exceeded 200 mm. in length.

Eques acuminatus (Bloch and Schneider)

Longley found that this species rarely left the shelter of the reefs at Tortugas. It is probable only strays from the snapper banks would be captured in shrimp trawls, and indeed, only two specimens were caught during this investigation. One was caught on the 24–10 grounds in 35–37 fathoms and the other was taken off Obregon, Mexico, in 19 fathoms.

Otolithidae

Cynoscion arenarius Ginsburg

Two species of sand trout live on the Texas coast. Gunter (1945) has discussed characters useful for field identification. The writer did not separate the two species until December, when he was thoroughly familiar with both species.

Seven thousand three hundred sand trout were counted, 4,000 on the Texas grounds, 290 on the 24–10 grounds, 595 on the Southwest Pass grounds, 870 on the Obregon grounds, and 550 on the white shrimp grounds off Sabine, Texas.

Although sand trout were found in all areas and all depths fished, few were caught in 31–37 fathoms on the 24–10 grounds. Seasonal movements of this fish are not well defined by my data. There is presumably an inshore movement during the spring and summer and an offshore one during the winter.

Nearly all fish caught offshore were large. Gunter (1945) found that this species was common in the bays and he was able to follow several size groups. Measured winter specimens from off the Texas coast ranged from 196 to 370 mm. However, the number of fish over 300 mm. long was small. Undoubtedly, many large, active fish avoid the trawl. Seven fish, ranging in length from 210 to 289 mm. (average 241 mm.), were caught in 32–34 fathoms on the 24–10 grounds on March 10, 1951. The size range of 94 fish which were caught in 15–17 fathoms off Obregon on August 4, 1951 was 210 to 375 mm. However, only three fish were more than 300 mm. long. Thirteen fish from a catch of 91 fish averaged 234 mm. long.

Sand trout probably have a long spawning season. Gunter found ripe gonads in April, May and June in Louisiana and during March in Texas. Four Obregon specimens, 210, 310, 315 and 375 mm. long respectively, had nearly ripe eggs, on August 4, 1951.

Little information was gathered on the food of this species; usually the stomach was empty and everted, probably due to pressure changes. Shrimp, a triglid, *Prionotus stearnsi*, and a small serranid, *P. pomospilus*, were occasionally seen in the stomachs.

Cynoscion nothus (Holbrook)

Ginsburg (1931) and Gunter (1945) have stated that this is an offshore species, while *C. arenarius* occurs more often inshore. Gunter further states that this species enters the more saline parts of the bays, especially during the winter. My data show that *nothus* was about three times as abundant as *arenarius* in the area studied. Information on the maximum bathymetric range of these two species has not been published, but the ranges overlapped completely in the area investigated.

Eighteen thousand five hundred small sand trout were counted, 6,770 on the Texas grounds, 4,400 on the 24–10 grounds, 51 on the Obregon grounds, 700 in Louisiana and 6,550 on the white shrimp grounds off Sabine. Several things should be emphasized.

This species was very rare on the Obregon grounds, and all sand trout from one drag in 17–18 fathoms were saved and examined carefully. The catch consisted of 94 *C. arenarius* and 1 *C. nothus*. Other checks proved that the rarity of *C. nothus* in the Obregon catch was not due to the sampling method. Perhaps, the rarity of *C. nothus* off Obregon was caused by heavy run-off from the Grijalva River. *C. nothus* was also much more abundant than *C. arenarius* on the 24–10 grounds in 31–37 fathoms. *C. nothus* was more common than *C. arenarius* in 7 fathoms off Sabine during June, 1951.

There was little seasonal variation in the sizes of trawl caught fish, although a number of small fish, 60 to 90 mm. long, were caught during May in 18 to 22 fathoms off Padre Island. Fish caught during the winter ranged in length from 160 to 204 mm. However, fish were not measured from every drag and probably larger and smaller fish were caught. Seventeen fish caught in 32–34 fathoms on the 24–10 grounds on March 4, 1951 ranged in length from 164 to 219 mm. and averaged 192 mm. long.

Little is known of the spawning season of this fish; presumably it is a long one and is concentrated in the fall of the year. Gunter (1945) took a specimen with ripe gonads in August. I did not often note the state of gonadal development, but one specimen taken off Obregon during early August had nearly ripe ovaries.

Branchiostegidae

Caulolatilus cyanops Poey

Specific determination of my material is questionable because of inadequate descriptions. However, my specimens match this species better than *C. microps*, the other species known from the Gulf.

A single specimen 113 mm. long was caught in 18 fathoms off Padre Island on July 10, 1951. This is the first reported occurrence of this species from the northwestern Gulf. Five additional specimens were taken in 17 to 19 fathoms off Obregon, Mexico during August, 1951. This species is evidently more abundant at depths greater than those now fished.

Ephippidae

Chaetodipterus faber (Broussonet)

Gunter (1945) found the spadefish in the shallow waters of the Gulf during the spring, summer and fall. The reverse was found to be true on the brown shrimp ground where it was more common during the winter. Spadefish occurred in nearly every trawl haul from October to June. None were taken during July in 12–18 fathoms off Padre Island and only one was seen at Obregon.

One thousand eight hundred and ninety spadefish were counted, 1,390 on the Texas grounds, 364 on the 24–10 grounds, 1 on the Obregon grounds and 135 on the white shrimp grounds off Sabine, Texas.

Most of the spadefish caught were small. The few specimens which were measured have a mode around 100 mm. The small catches may indicate that the spadefish frequents hard bottom or obstructions. Newspaper accounts of large spadefish caught from the oil well platforms in the Gulf of Mexico off Louisiana have been frequent during recent years, and occasionally spadefish are caught from the jetty and fishing piers at Port Aransas, Texas.

Cataphracti

Scorpaenidae

Scorpaena calcarata Goode and Bean

Fishermen know this little red fish well, as its "sting" is painful. It is much commoner on the Lobos Island grounds and off Campeche, Mexico, than it is in the northern Gulf. Seven hundred and seventy-six specimens were counted, 53 on the Texas grounds, 52 in Louisiana, 270 on the 24–10 grounds and 401 on the Obregon grounds. This is a small species and it rarely exceeds 120 mm. in length. Gunter (1948) reported that it was the commonest scorpaenid of the south Atlantic and Gulf coasts in depths of 8 to 35 fathoms, and the numbers caught here tend to confirm that statement.

Scorpaena dispar Longley and Hildebrand

Little is known of the distribution of this species in the western Gulf. Its bathymetric range is not known; the type was taken off the Tortugas Islands in 40 fathoms. Eleven specimens were caught in 21 to 40 fathoms on the 24–10 grounds. Five specimens ranged in length from 130 to 140 mm.

Scorpaena plumieri Cuvier and Valenciennes

Eighteen fish were taken off Obregon, Mexico, in 15 to 20 fathoms of water. After one has seen this species concealing itself among the rocks of the Port Aransas jetty, it is hard to imagine that this rockfish also lives on mud bottom. Three specimens measured 230, 246, and 275 mm. respectively.

Peristediidae

Peristedion imberbe (Poey)

A single fish, 89 mm. long, was caught in 17 to 19 fathoms off Obregon, Mexico. This fish is obviously a stray from deeper water as Longley reports the species as common in 40 to 95 fathoms off Tortugas (Longley and Hildebrand, 1941).

Triglidae

Prionotus ophryas Jordan and Swain

One hundred and eighty-eight fish were counted, 84 on the Texas grounds, 66 on the 24–10 grounds and 38 on the Obregon grounds. The size range was 64 to 143 mm. The smallest specimen was caught in July off Padre Island. This sea robin was never abundant. A careful search would seldom reveal more than two or three fish per drag. Little information is available on the bathymetric range of this species. I took the species in 12 to 40 fathoms.

Prionotus paralatus Ginsburg

This triglid was recently described by Ginsburg (1951), and all his specimens were caught along the Texas coast in 24–90 fathoms. Most of its bathymetric range is beyond the area investigated.

Three hundred and seventy triglids were counted, 270 on the Texas grounds, 50 on the 24–10 grounds and 16 on the Obregon grounds. This species was taken in 12 to 40 fathoms and it was most abundant during the summer. Small specimens 49 to 79 mm. long were caught during May. The largest specimen was only 128 mm. long and this indicates that only the young stray inshore.

Prionotus pectoralis Nichols and Breder

Ginsburg gives the bathymetric distribution of this species as 6 to 35 fathoms. It is known from Cape Hatteras, North Carolina to Texas.

This species was not at first definitely recognized in the field. Doubtful specimens which were saved for more careful examination in the laboratory confirm that this species was present in the catch during November, December, January and March. However, the percentage seemed low.

Three hundred and thirty-four sea robins were counted, 330 on the Texas grounds and 4 on the Obregon grounds. They were taken in all depths from 12 to 36 fathoms, but they were never abundant.

The few measurements that were recorded range from 125 to 223. No special relationships between size and bathymetric distribution were noted.

Prionotus rubio Jordan

Ginsburg gives the range of this species as the shallow waters of the inner bays on the north Gulf coast to 89 fathoms. He further states that it is the most common triglid in the shallow waters of the northern Gulf.

Seventeen thousand nine hundred specimens were counted, 4,740 on the Texas grounds, 10,400 on the Southwest Pass grounds, 386 on the 24–10 grounds, 2,180 on the Obregon grounds and 200 on the white shrimp grounds off Sabine, Texas. It was the most abundant fish on the mud bottom in 19 to 22 fathoms off Louisiana during June, 1951.

Size ranges of this species varied seasonally and bathymetrically, but adequate measurements were not taken to show these changes. Specimens caught during the winter ranged in length from 144 to 213 mm. At least two size groupings were present in the Louisiana catch, where the sea robins ranged in length from 100 to 190 mm. Only small specimens, 53 to 73 mm., were caught in 3 to 7 fathoms off Sabine, Texas.

Little information was gathered on spawning; apparently it is a long spawning season. Ripe females were observed during January, 1950.

Prionotus scitulus latifrons Ginsburg

The type locality of this triglid is Rockport, Texas. Ginsburg (1950) gives a bathymetric range of 2 to 25 fathoms. Gunter (1945) has reported this species from the bays during the winter months.

A single specimen 149 mm. long was caught in 18 fathoms off St. Joseph Island during December.

Prionotus stearnsi Jordan and Swain

This little triglid is widely distributed in the Gulf. Ginsburg (1950) examined specimens from the Rio Grande to the Tortugas Islands. The bathymetric range was 13 to 169 fathoms.

One thousand one hundred and thirty triglids were counted, 315 on the Texas grounds, 170 on the 24–10 grounds and 645 on the Obregon grounds. I caught this fish in depths of 12 to 40 fathoms, but I did not find it off Louisiana. No fish were caught during the winter in less than 24 fathoms. The abundance of this little triglid is even more impressive when the inadequacy of the gear for its capture is considered.

The largest specimen was 90 mm. and the smallest was 33 mm. The smallest fish was captured during January. Longley found ripe females during August off the Tortugas Islands (Longley and Hildebrand, 1941).

This is one of the important forage fishes in the western Gulf. I have found this fish in the stomachs of snapper, *Lutianus blackfordi*, sea bass, *Centropristes philadelphicus*, sand trout, *Cynoscion arenarius*, and the lizardfish, *Synodus foetens*.

Prionotus tribulus crassiceps Ginsburg

This species has a very limited range along the northern Gulf coast. It occurs in the shallow bays and in the Gulf out to 15 fathoms according to Ginsburg (1950).

Two hundred and ninety *P. tribulus* were counted, 230 on the white shrimp grounds off Sabine, one on the Texas grounds, 8 on the Obregon grounds and 50 on the Louisiana grounds. The maximum depth of capture was 23 fathoms off Grand Isle, Louisiana. However, only a few large adults were taken in water deeper than 12 fathoms. This species was common in 6–7 fathoms off Sabine, but only a few fish were caught elsewhere.

Triglids, ranging in size from 91 to 249 mm., were taken off Sabine. Most of the other specimens taken in deeper water were large; and they measured more than 175 mm. An Obregon specimen 215 mm. long had nearly ripe roe during the first week of August.

Bellator militaris (Goode and Bean)

The soldier sea robin is a very distinctive triglid. Ginsburg (1950) gives the bathymetric range of this species as 22–60 fathoms.

Four hundred and sixty-one fish were counted, 82 on the 24–10 grounds and 380 on the Obregon grounds. They were caught in depths of 13 to 40 fathoms. However, they were very rare in depths of less than 19 fathoms. Probably this species moves closer to shore during the summer; at least no soldier sea robins were caught during the winter months in 17 to 24 fathoms.

This is a small species, but it entangles easily in the net because of its long rostral "horns" and general roughness. My specimens ranged in length from 74 to 90 mm.

Dactylopteridae

Dactylopterus volitans (Linnaeus)

A single flying gurnard, 62 mm. long, was caught in 17–19 fathoms off Obregon, Mexico. This is a very common species on the Campeche Bank.

Gobiodea

Gobiidae

Gobionellus gracillimus Ginsburg

Two specimens of this slender goby were captured. The middle rays of the tail are prolonged and often broken; consequently, these gobies were measured to the base of the caudal fin. One goby 56 mm. long was caught in 20 to 21 fathoms south of Greens Bayou on December 19, 1951. Another goby 71 mm. long was caught in 21–22 fathoms off Padre Island on May 17. Ginsburg (1953), who recently described this species, had no specimens from depths greater than 10 fathoms.

Bollmannia communis Ginsburg

A large shrimp trawl is not suitable for catching this species, but it appeared in almost every trynet drag on the brown shrimp grounds. It was considered one of the trademarks of the brown shrimp grounds.

Seven hundred and seventy gobies were counted, 485 on the Texas grounds, 20 on the 24–10 grounds, 260 on the Obregon grounds and 1 on the Louisiana grounds. These figures have little bearing on the abundance of this species for it easily escapes through the large mesh trawls. I have seen as many as 30 specimens in a 20 minute trynet haul. This species is rare in less than 15 fathoms. The standard length of specimens caught during this investigation ranged from 40 to 74 mm.

Discocephali

Echeneidae

Echeneis naucrates Linnaeus

Remoras are usually captured with large fish to which they are attached. Nine were caught, six off Sebree Bank, attached to a large sawfish, *P. pectinatus*, one off St. Joseph Island, attached to a hammerhead shark, and two off Obregon, attached to a large jewfish, *P. itaiara*.

Jugulares

Opisthognathidae

Lonchopisthes lindneri Ginsburg

Five specimens of the diminutive jewfish were caught. One was taken in a drag off Sebree Bank on the Texas coast, and the remaining four were taken off Obregon. In two instances, some shell was present in the net, and it is probable that this little jewfish prefers shell bottom.

Uranoscopidae

Kathetostoma albigutta (Bean)

The greatest abundance of this species is evidently beyond the depths now fished by the commercial shrimp fishermen. One hundred and thirty specimens were counted, 129

on the 24–10 grounds and 1 on the Texas grounds. None were taken in water of less than 24 fathoms.

One female 163 mm. long containing nearly ripe roe was taken in 24 fathoms off Corpus Christi Pass. The size range of uranoscopids caught on the 24–10 grounds was 138 mm. to 185 mm.

Brotúlidae

Execestides egregius Jordan and Thompson

One specimen which agrees well with the figure and original description of this species was caught in 21–31 fathoms on the 24–10 grounds during March, 1951. This species has not been previously recorded from the northern Gulf. Possibly, this species may represent the young of some other uranoscopid in the Gulf. My specimen was only 87 mm. long.

Brotula barbata (Bloch and Schneider)

Two hundred and fifty brotulids were counted, 39 on the Texas grounds, 1 on the 24–10 grounds, and 210 on the Obregon grounds. As no brotulids were taken during the winter months in 17–24 fathoms, it is probable that this species moves into shallower water during the summer and retreats offshore during the winter. The size range was 116 mm. to 230 mm. The smallest specimen was taken during July off the Texas coast.

Ophidiidae

Lepophidium brevibarbe (Cuvier)

At one time the cusk eel was considered a rare fish in the western Gulf. This long slender fish is not readily captured in a trawl, although it does not appear to be nearly so active as some of the true eels.

Thirty-nine hundred cusk eels were counted, 710 on the Texas grounds, 13 on the Southwest Pass grounds, 227 on the 24–10 grounds, 2,950 on the Obregon grounds. Possibly this species was much more abundant in the Obregon grounds as the catch records indicate, but the increased capture could be due in part to the short period of actual trawling, and also because the trawl was usually hoisted aboard there immediately without much washing. This species was not taken in water of less than 12 fathoms during this investigation.

Few measurements were taken. The two smallest specimens observed were 37 and 58 mm. long, and they were caught in 24 fathoms off Corpus Christi Pass during January.

Otophidium welshi Nichols and Breder

Nine specimens of this cusk eel were caught, one on the white shrimp grounds off Sabine, and eight in 12 to 13 fathoms off Wine Island Pass, Louisiana. This species evidently prefers shallower water than the preceding species.

Rissola?

One small cusk eel 105 mm. long was taken from the webbing of the shrimp trawl in 35–37 fathoms on the 24–10 grounds. It has tentatively been referred to this genus.

Batrachoididae

Nautopaedium porosissimum (Cuvier and Valenciennes)

Thirteen thousand midshipmen were counted, 1,240 on the Texas grounds, 160 on the 24–10 grounds, 55 on the Southwest Pass grounds, 11,550 on the Obregon grounds and 4 on the white shrimp grounds off Sabine. This species was taken in all depths from 3 to 40 fathoms. Gunter has also reported this species from the Texas bays.

Size measurements for Texas specimens ranged from 78 to 173 mm. A large number of the Obregon specimens were small and the mode was around 90 mm.

One female 125 mm. long which was caught on the 24–10 grounds during March had large, nearly ripe roe.

Plectognathi

Balistidae

Balistes capriscus (Gmelin)

Triggerfish were never abundant, and rarely more than one or two fish were caught per drag. One hundred and fifty-four fish were caught, 108 on the Texas grounds, 3 on the Southwest Pass grounds, 5 on the Obregon grounds, and 1 on the 24–10 grounds. Triggerfish were caught in depths of 12 to 24 fathoms. Nearly all the fish were small and they rarely exceeded 200 mm. in length. Large triggerfish are sometimes caught on the snapper banks where they have a bad reputation as a bait stealer.

Monacanthidae

Monacanthus hispidus (Linnaeus)

Fifteen foolfish were caught, 11 on the Texas grounds, 2 in Louisiana and 2 on the Obregon grounds. This little fish was not common anywhere in the western Gulf. It was taken in depths of 12 to 24 fathoms in the large trawl and in 6 fathoms off St. Joseph Island in a trynet during October, 1950. No seasonal trend in its distribution was noted. Reid (1954) found this species most common during the warm months at Cedar Keys, Florida. The same appears to be true of Texas. Large numbers enter the bays and shallow water in the spring as hitchhikers in the sargasso weed.

Alutera schoepfi (Walbaum)

Ten specimens of this species were taken during October in 15 fathoms off the Texas coast. These were large specimens ranging in length from 279 to 305 mm.

Alutera ventralis Longley

Twelve mall specimens of this species were caught. They were all caught at Obregon. The depth range was 14–20 fathoms. The largest was 164 mm. and the smallest was 65 mm.

Ostracidae

Lactophrys tricornis (Linnaeus)

One hundred and twenty-one cowfish were counted, 60 on the Texas grounds, 14 on the Southwest Pass grounds and 47 on the Obregon grounds. It was never taken in great numbers, but it appeared in almost all drags on the Obregon grounds. Cowfish were taken in depths of 12 to 24 fathoms. This species was found to be very abundant on Campeche Bank in 6–10 fathoms during February.

Tetradontidae

Lagocephalus laevigatus (Linnaeus)

Five hundred and sixty rabbit fish were caught, 498 on the Texas grounds, 68 on the Obregon grounds, 5 on the Southwest Pass grounds and 24 on the 24–10 grounds. This species was caught in depths of 6 to 35 fathoms. The largest specimen captured was 370 mm. long and it was a spent female. Most of the fish caught were less than 200 mm. long.

Sphoeroides nephelus (Goode and Bean)

Considerable confusion exists as to the species of puffers in the Gulf of Mexico. Mr. Loren Wood of the Chicago Natural History Museum has identified the common puffer of the northern Gulf as the above species. The species Gunter (1945) reported as *S. marmoratus* from the Texas coast should be synonymized with *S. nephelus*.

This is the common puffer of the Texas coast. Seven hundred and thirty were caught, 505 on the Texas grounds, 165 on the Obregon grounds, 35 on the Southwest Pass grounds and 24 on the 24–10 grounds. Puffers were caught in depths of 6 to 35 fathoms, and they have also been reported from the shallow water of the Texas bays and the surf on the Texas beaches (Gunter, 1945).

No large specimens of this species were seen on the Texas coast. Nearly all the puffers were less than 100 mm. long.

Sphoeroides dorsalis Longley

Longley reported this species from Tortugas in depths of 10 to 40 fathoms. Seven specimens of this species were seen. Four were taken in deep water, 31 to 40 fathoms, on the 24–10 grounds, and the remaining three were taken on the Obregon grounds. The habitat preference of this species is unknown, although Longley's specimens, like mine, were taken in otter trawls. It would appear that offshore along the northeastern coast of Mexico this species replaces *S. nephelus*.

Sphoeroides testudineus (Linnaeus)

This species has been reported from the Galveston area of the Texas coast (Baughman, 1950). I did not take it in Texas waters. Nineteen specimens were caught on the Obregon grounds. Four specimens ranging in length from 203 to 213 mm. were measured. This fish was not uncommon on the Campeche Bank during February, 1951.

Sphoeroides spengleri (Bloch)

A single well marked specimen 117 mm. long was taken in 24 fathoms north northeast of Brazos Santiago. This is one of the few records of this species from the Texas coast. This fish may prefer shell sand as it was not uncommon off Campeche, Mexico, during February, 1950, and its capture on the Texas coast was close to a snapper bank and shell sand.

Diodontidae

Chilomycterus schoepfi (Walbaum)

Forty-seven box fish were counted, 13 on the Texas grounds, 3 on the Southwest Pass grounds, and 31 on the Obregon grounds. This species was more common in the summer catches than during the winter. Small specimens less than 2 inches long were taken in trynet hauls in 3 fathoms during October, 1950.

Pediculati

Antennaridae

Antennarius radiosus (Garman)

This is the common frogfish on muddy bottom in the western Gulf. Four hundred and twenty fish were counted, 305 on the Texas grounds, 50 on the Southwest Pass grounds, and 64 on the Obregon grounds. The species was caught in depths of 12 to 40 fathoms.

This frogfish eats chiefly fishes. Eels, *Congrina flava*, and *Hoplunnis macrurus*, a small *A. scaber* and large quantities of unidentified fish remains were found in the stomachs.

Ogcocephalidae

Ogcocephalus

The Gulf has a rich and varied fauna of batfishes, but I have recognized only two species in my collection. One species does not appear to have a name, but the taxonomy of the genus is very confused and a revision is badly needed. The other species encountered is *O. cubifrons* (Richardson), as understood by Longley (1941).

As the batfishes were not separated in the field, the grouped data for the genus are presented. One thousand three hundred and thirty batfish were counted, 1,170 on the Texas grounds, 130 on the 24–10 grounds, 2 on the Southwest Pass grounds, and 23 on the white shrimp grounds off Sabine. No batfishes were observed on the Obregon grounds, although a special search was made for this genus.

Ogcocephalus cubifrons (Richardson)

I collected 12 specimens of this species. Eleven were caught on the white shrimp grounds off Sabine, Texas in 7 fathoms. *O. cubifrons* was the only species of batfish observed in the shallow water off Sabine. The other fish, 272 mm. long, was taken off St. Joseph Island in 17–19 fathoms during December, 1950. This species, as Longley (1941) has previously stated, is the common inshore species in the western Gulf.

Ogcocephalus sp.

A small batfish (the largest examined around 160 mm.) with a short nose and 11 pectoral rays is the most abundant species on the brown shrimp grounds. I have not been able to place this fish in any species known from the Gulf and it may represent a new species. However, the taxonomy of the genus is so confused that a revision of the entire genus will be required to correctly place my specimens.

Sixty-six fish are in the Institute of Marine Science collection. The bathymetric range of these fish is 12–37 fathoms. This was the only species observed on the 24–10 grounds and off Louisiana, and it was not seen on Campeche Bank or at Obregon. The food of this species appears to be small bottom organisms such as snails, xanthid crabs, hermit crabs and small eels. Dr. Harald Rehder identified 9 small gastropods and one small clam, *Corbula swiftiana,* from the stomachs of batfish caught in 25–26 fathoms off Mustang Island during April, 1954. *Anachis calliglyphta* was the most common gastropod in the stomachs.

Halieutichthys aculeatus (Mitchill)

Five hundred and ten specimens were counted, 163 on the Texas grounds, 270 on the Obregon grounds, 63 on the 24–10 grounds and 6 on the Southwest Pass grounds. This fish was caught in depths of 12 to 42 fathoms. Forty fish were caught in a 30 minute trynet haul in 40 to 42 fathoms at 24° 10′ N. Four were taken in a trynet in 12 fathoms east of Freeport.

GENERAL DISCUSSION OF THE FAUNA

Mollusca

Shells cause net destruction and shrimp fishermen avoid the so-called "shell piles" along the Texas coast, whenever possible. In contrast to Campeche, shell banks rarely prove productive in Texas waters. Only one of the two areas (Freeport) of reported shell concentration along the Texas coast was examined by a few sweeps of the trynet, and the data presented refer to the mud bottom flats of the shrimping grounds.

The selectivity of the gear used has already been discussed, and the accompanying tables show that few mollusks are caught in trawls on the muddy ocean floor, where the brown shrimp are caught. Some 57 species of mollusks are recorded in the entire area investigated, with the exception of Campeche Bank. Four of these were common on the white shrimp grounds closer inshore. These are *Pitar texasiana, Polynices duplicata, Arca campechiensis,* and locally *Thais haemostoma.* Thirty-two species appeared in the catches only rarely. Two species were mainly confined to the shell bank off Freeport; both *Echinochama arcinella* and *Strombus alatus* were abundant there. Twenty species were common on the brown shrimp grounds, although the squid, *Lolliguncula brevis,* is apparently common only during the winter season.

Large whelks were the most common mollusks in trawls on the brown shrimp grounds. *Busycon contrarium* was slightly more common than *Busycon pyrum. Pitar cordata* appeared most often in the trynet and it is the most common pelecypod on the brown shrimp ground. Two other species that should rank high in the order of abundance, although they are seldom taken in the big net, are *Macoma tageliformis* and *Chione*

clenchi. These two species were very common in trynet hauls. *Chione* appeared to be more common inside of 20 fathoms, while *Macoma tageliformis* occurred throughout the area. Some species, like *Pecten papyraceus, Conus austini,* and *Polystria albida,* appeared only in the deepest water fished and have their main center of abundance beyond the bathymetric range of the present fishery.

Pulley (1952) has commented on certain shells that are more common at Port Isabel than at Sabine, apparently without recognizing that these remarks can only apply to inshore waters. The 10 fathom curve is only five miles from the beach at Padre Island while it is nearly 30 miles offshore at Sabine. Furthermore, the shore waters are of much lower salinity on the east Texas coast. Some shells may actually be more abundant offshore at Sabine, but rarely wash ashore there. This seems to be true of *Murex fulvescens* which is much more abundant off Sabine than off Port Isabel, according to fishermen reports, but only near Port Isabel are the fresh shells taken along the shore, as Pulley (*op. cit.*) reported. I noted no particular break in mollusk fauna between Sabine and Port Isabel in trawling operations, although I did notice a difference in the jetty fauna (see Whitten *et al.,* 1950). Comparison between the Obregon and the Texas grounds is difficult because very few shells were taken off Obregon. Two species were taken off Obregon that were not found in the northern Gulf. They were *Fusinus couei* and *Busycon coarctatum.* They are isolated specimens.

There is a decided difference between the shell fauna of Campeche Bank and that of the Texas coasts. Dominants in the Campeche fauna, such as *Xancus angulata, Busycon coarctatum,* are unknown and two others, *Fasciolaria tulipa* and *Fasciolaria gigantea,* are rare on the Texas coast.

TABLE 7

The Nineteen Most Abundant Mollusks in Trawls on the Brown Shrimp Ground (12–37 Fathoms) in the Western Gulf of Mexico

	All Areas Total No. Specimens	Southwest Pass No. Drags	Southwest Pass Grounds	Texas No. Drags	Texas Grounds	24–10 No. Drags	24–10 Grounds	Obregon No. Drags	Obregon Grounds	No. Drags
Pelecypoda										
Atrina serrata*	60	2	0	0	60	2	0	0	0	0
Pecten papyraceus*	9	8	0	0	2	2	7	6	0	0
Laevicardium laevigatum	13	10	1	1	6	5	6	4	0	0
Chione clenchi*	2	2	1	1	1	1	0	0	0	0
Pitar cordata*	77	36	0	0	66	23	8	10	3	3
Macoma tageliformis*	2	2	----	----	1	1	0	0	1	1
Gastropoda										
Phalium granulatum	44	20	1	1	28	16	2	2	13	2
Sconsia striata	8	7	0	0	2	4	2	3	1	1
Distorsio clathrata*	35	11	2	1	19	7	13	2	1	1
Tonna galea	32	18	0	0	15	11	2	2	15	5
Murex fulvescens	9	7	1	1	6	3	1	1	1	1
Busycon contrarium	149	43	2	2	123	26	8	4	16	11
Busycon pyrum	103	19	0	0	65	14	0	0	8	5
Fasciolaria distans*	5	3	3	2	0	0	0	0	2	1
Fasciolaria gigantea	4	4	0	0	4	4	0	0	0	0
Conus austini*	5	8	0	0	1	1	2	5	1	1
Polystria albida	29	11	0	0	7	3	5	4	19	5
Cephalopoda										
Lolliguncula brevis	1700	13	750	3	950	9	0	0	3	1
Loligo pealei	4770	57	250	4	3300	30	220	5	1000	18

* More common in trynet (often not counted).

The dominant mollusks on the mud bottom of the Texas grounds are *Busycon contrarium*, *Busycon pyrum*, *Pitar cordata*, and *Distorsio clathrata*. Locally *Atrina serrata* occurs in great abundance, and this was particularly noted in the region near Sebree Bank. The entire extent of the 24–10 brown shrimp grounds was not investigated, but in the 30 to 40 fathom zone, *Pecten papyraceus*, *Pitar cordata*, *Laevicardium laevigatum*, *Distorsio clathrata* and *Polystria albida* were dominant. On the Obregon grounds, mollusks were very rare, but the dominant species were *Tonna galea*, *Polystria albida* and *Phalium granulatum*. The absence of *Pitar cordata* from the list of dominant mollusks on the Obregon grounds was possibly due to the use of the "jumper chain" instead of leads.

Shrimp

Nine species of shrimp were found more or less commonly during this investigation. All nine species belong to the family Penaeidae, which is beyond all odds the most abundant benthic family in the shallow waters (shoreward of the 40-fathom contour) of the western Gulf of Mexico. The bathymetric range of all nine of the shrimp species overlap, but the adults of *Penaeus aztecus* are more abundant at depths beyond those inhabited by *P. setiferus*.

As investigation of the white shrimp grounds was only incidental to the main task, I visited the white shrimp grounds only during October, December and June. Approximately 186,000 shrimp were caught in the large net and the average per hour was 122 pounds, the average per acre being 3.9 pounds. Acreage was computed by considering 80 per cent of the length of the foot rope as the effective fishing width of the net. An average figure of 2½ knots was used for computing distance trawled.

A word of caution should be interjected as to meaning of the average catches. First, it must be remembered that white shrimp often travel in dense "schools," and that even the catch of two boats made at the same time and in the same general area cannot be compared with confidence for one boat may pass through the school and the other may miss it entirely. Secondly, the spring of 1951 was a very poor season, and bait dealers at Freeport and Port Isabel stated emphatically that it was the worst in history. Very few boats made good catches of white shrimp. During 1941–42 white shrimp were many times more abundant (see Gunter, 1945, 1950).

Comparative studies on the catch of white shrimp during the day and night have not been published, yet it is unlikely that, because of night fishing, any large concentration of white shrimp was undetected during this investigation. Shrimp fishermen are inquisitive and continually prospect for better shrimping. Daytime drags were attempted by a few of the fishermen nearly every day, but no concentrations of white shrimp were found on the brown shrimp grounds. Several white shrimp were taken in 21–23 fathoms off Padre Island and these represent the bathymetrical depth record for *P. setiferus* during this investigation.

Another interesting observation is that the species mass of the croakers, *Micropogon undulatus*, was found to be greater than that of the white shrimp in the Sabine area of east Texas during June. The croaker has always been abundant in the inshore waters of Texas and Louisiana and this predominance increases eastward (*Cf.* Gunter, 1936, 1938, 1945), but the fishermen seem to think they have increased as the white shrimp declined and the observations off Sabine certainly tend to corroborate that idea.

The abundance of brown shrimp along the south Texas and Tamaulipas coasts was not realized until night fishing was undertaken. Anderson is quoted in the September,

1948 issue of the Seafood Business Magazine as stating that the "Pelican" caught brown shrimp, *P. aztecus,* in nearly every drag off Padre Island, but that no large populations were indicated by the number of shrimp caught. Anderson was evidently comparing the scattered brown shrimp with the denser concentration of white shrimp in his experience. On the other hand it is entirely possible that brown shrimp have increased in numbers as the white shrimp declined since 1947. Both species raise in the bay waters and there may be competition between the two, especially in younger stages. Gunter (1950) has shown that the periods of maxima and minima of the two species in Texas bays do not coincide. When a market for brown shrimp was firmly established, the fishery expanded at a prodigious rate.

Brown shrimp, *P. aztecus,* had the greatest species mass of any benthic animal caught in the otter trawls. Only in the area inside eight fathoms did the white shrimp exceed this species in abundance. Fishermen have speculated on the recent abundance of *Penaeus aztecus* in the bay and offshore waters of Texas and many consider the brown shrimp to be a recent invader of the bays. Collier (1938) and Gunter 1945, 1950) found the brown shrimp common in the bays during the period of greatest production of white shrimp on the Texas coast. Gunter found brown shrimp, *P. aztecus,* in the Texas bays throughout the year in 1941 and 1942, but at no time did it form the basis of a fishery. Weymouth, Lindner and Anderson (1933) found a similar situation in Louisiana in 1931–1932. However, nearly all the shrimp caught in the bays of Texas, except Sabine Lake, during May and June, 1951 were brown shrimp, *P. aztecus.* The best explanation of this change in fauna of the Texas bays appears to be changed physical conditions, for which the prolonged drought in Texas is probably responsible (Hildebrand and Gunter, 1953).

Approximately 1,360,000 brown shrimp were caught during the investigation, at the average rate of 128 pounds per hour and 4 pounds per acre. The greatest abundance was during July and August. The least abundance occurred during the spring months.

Seabobs, *Xiphopeneus krøyeri,* are limited to a narrow zone along the coast. Approximately 10,000 seabobs were caught, none at any greater depth than 8 fathoms.

Trachypeneus similis is a small shrimp and undoubtedly many escape through the meshes of the trawl. Nevertheless, only *P. aztecus* among the shrimp was more abundant in trawl hauls at 10 to 25 fathoms on mud bottom.

Three species of *Sicyonia* were caught in shrimp trawls. *S. typica* is known from a few specimens from the Obregon grounds. This species is chiefly tropical in distribution. *S. dorsalis* is the common "hard shell" shrimp on the brown shrimp grounds. Several peculiarities in the distribution of *S. brevirostris* have been discussed under the account of the species. At present there is too little information available, but possibly it is limited to a hard substrate, or perhaps competition from *S. dorsalis* limits the range.

Solenocera vioscai lives along the seaward edge of the present fishery but most of its bathymetric range is at still greater depths. Some evidence of an inshore migration during the summer was obtained, but more information from extensive trawling in the 20 to 30 fathom zone is needed.

From the shore to ten fathoms, the dominant species of peneid shrimp in the northwestern Gulf are *Penaeus setiferus* and *Xiphopeneus krøyeri.* At times young *Penaeus aztecus* are very abundant in shallow water, but the adults occur in deeper water. *Penaeus aztecus, Trachypeneus similis* and *Sicyonia dorsalis* are dominant in the 12

to 25 fathom zone. *Penaeus aztecus, Trachypeneus similis* and *Solenocera vioscai* were dominants in the 30 to 40 fathom zone on the 24–10 grounds. The distribution of the different species of shrimp should not be plotted as continuous bands between prescribed depth limits as some authors have done. There are discrete fishing grounds for brown shrimp and the other species as well in the Gulf, which are related to the type of bottom and the inshore nursery grounds. Moreover, white shrimp, *Penaeus setiferus*, are often found in commercial quantities out to 25 fathoms off Louisiana, and it is rarely fished in depths greater than 16 fathoms in Texas waters.

Anomura

Hermit crabs are dependent on an adequate supply of empty shells. Large shells were rare on the mud bottoms of the brown shrimp grounds. The common hermit crab was *Petrochirus bahamensis*. Usually the little louse crab, *Porcellana sayana*, was attached to this hermit crab.

Crabs

Twenty species of crabs were particularly noted during this investigation. Undoubtedly, the species list would be longer if I had particularly searched for small xanthid and spider crabs.

Callinectes danae occurred in the greatest abundance. Nowhere in the brown shrimp ground was the abundance of this crab exceeded by another brachyuran. In one drag in 21–23 fathoms off Grand Isle, Louisiana, the lady crab, *Ovalipes ocellatus*, was nearly as abundant, but this species was not found elsewhere in shrimp trawls. Next to the brown shrimp, the Gulf crab was the most abundant animal in the trawls. It is just as abundant on the inshore white shrimp grounds (Gunter, 1950).

Calappa springeri is a large and conspicuous crab. It occurred in nearly every drag except on the Obregon grounds where only three small specimens were taken. Never did I see any indication of a large population of this species.

Arenaeus cribrarius, Persephona p. aquilionaris, P. crinita and *Hepatus epheliticus* prefer the shallower water of the white shrimp grounds and they were only sporadically found on the brown shrimp grounds.

The bathymetric range of *Portunus spinicarpus* is chiefly beyond that of the present fishery. This species occurred in some abundance in depths greater than 20 fathoms.

Spider crabs occurred only sporadically in the trawl catches. Occasionally a few common spider crabs, *Libinia emarginata*, were taken in the trawls in 12 to 20 fathoms, but other species of spider crabs were rare. *Stenocionops spinosissima* occurred only in depths greater than 30 fathoms, where one or two specimens per drag were caught.

Echinoderms

Except for the small starfish, *Astropecten antillensis*, no echinoderm was widely distributed on the shrimp grounds. *Astropecten antillensis* was excessively abundant on the brown shrimp grounds, but it was too small to be captured in the large net.

In limited areas of the Gulf, sand dollars are known to be extremely abundant. *Mellita quinquiesperforata* is very common in three to four fathoms along the coast of St. Joseph and Matagorda Islands. *Clypeaster ravenelli* prefers deeper water and is

known on the Texas coast only from 24 fathoms off Port Isabel, where it carpets the ground.

Indications of a large population of heart urchins in 14 fathoms northeast of Shipshoal Buoy were seen in a trynet haul. Burkenroad (1939) reports large numbers of heart urchins off the Louisiana coast in 65 fathoms of water.

Starfish fauna changes quite sharply as the depth of water increases. Large conspicuous red starfish, *A. cingulatus,* were found only in depths greater than 25 fathoms.

The large starfish, *Oreaster reticulatus,* was abundant on the Campeche Bank, but it has not been recorded from the Texas coast. *Echinaster echinophorous* appears to be more common on Campeche Bank than along the Texas coast.

Pisces

It is necessary to mention a few of the many factors that influenced the catch of fish during this investigation. Since no regular stations were maintained throughout a calendar year, seasonal changes in abundance can only be inferred from operations in adjacent areas. Moreover, eleven different shrimp trawlers were used during this investigation. Although much of the equipment is standard throughout the fleet, there are some variations that affect the catch of fish. One important variation is the size of the trawls. Trawls, ranging in width from 85 to 135 feet, were used. One might expect more large fish to be taken in a large trawl as many of the fish near the center of the net would be unable to escape around the ends. Two nets rarely fish the same, and usually more than one net is used during a fishing trip. Furthermore, the crew continually strives to improve the fishing quality of the gear by making minor adjustments.

Although it is difficult to measure objectively, the efficiency and experience of the crew are important. All boats used during this investigation were operated by experienced fishermen. One had led the fleet in landings during 1949, and most of the other boats were operated by fishermen with high production records.

The primary purpose of the trips was to catch shrimp, and fish are usually scarce where shrimp are very abundant. Shrimpers must work harder if fish are abundant, because the net must be lifted more often, and the task of sorting the catch is more arduous. During June, 1951 much trawling time was lost because it was necessary to search for an area where fish were less abundant. Certainly many more fish could be caught if catching fish were the object.

I mentioned above the diurnal migrations of certain fishes, under the accounts of species which seem to exhibit this phenomenon. Although fish catches were greater during the daytime than at night, the few daytime hauls do not provide enough data for a thorough analysis. Unfortunately, shrimp fishermen stop trawling at daybreak on the brown shrimp grounds except under circumstances such as rough seas, cloudy weather, or during the full moon. These variables add complicating factors to the comparison of day and night catches. When fishing for white shrimp, most fishermen anchor at night because of the reduced catches. I made no night drags on the white shrimp grounds. Whether the much greater catches of fish on the white shrimp grounds are an indication of greater population of fish or merely related to night and day fishing remains to be investigated.

The limitations of the gear particularly for catching small or pelagic fishes have been discussed. Certain small benthic fishes such as the goby, *Bollmannia communis,*

must be extremely abundant, as it was the most common fish in the trynet hauls. However, there was no evidence that the trawl was more selective on one fishing ground than another.

In order to compare the abundance of the different fishes, I found it necessary to divide the fishing grounds into several subdivisions. Bathymetrically the twelve fathom contour was used as the dividing line between the brown and white shrimp grounds. This is an arbitrary line and certainly does not apply to the winter fishing off Louisiana. However, all drags except four drags in Louisiana fell readily into white or brown shrimp grounds on the basis of this dividing line. Four drags in 12 to 13 fathoms off Wine Island Pass in Louisiana are certainly on the borderline between the white and brown shrimp fishery, and most of the fishing was done there during the day. I have discussed these four drags under both the white shrimp and brown shrimp fishery in the section on shrimp, but in this section I have grouped these drags with the brown shrimp fishery.

Gunter (1935, 1936, 1938, 1945) has discussed the distribution of fishes in the shallow waters of Texas and Louisiana. He investigated the offshore fauna from the coast to ten fathoms in Texas. However, most of his stations were in the bays, a region which I did not visit.

I spent 36 hours trawling on the white shrimp grounds exclusive of the four Louisiana drags. Nineteen drags were made, ten during October, one in December, and eight during June.

During October the writer spent 17 hours and 45 minutes trawling on the white shrimp grounds from Pass Cavallo to the Colorado River. This trip has been previously described. Nearly all the time was spent becoming familiar with fishing methods and the fauna and although the species were recorded, few numerical data were collected. The number of species recorded per drag varied from 18 to 30 species and the average was 23. Forty-five species were recorded. These species arranged systematically are as follows:

TABLE 8

Species of Fish Caught During October Between Pass Cavallo and the Colorado River in 3–8 Fathoms

Sphyrna tiburo
Rhinobatus lentiginosus
Raja texana
Narcine brasiliensis
Dasyatis sabina
Harengula pensacolae
Brevoortia patronus
Anchoa hepsetus
Anchoa mitchilli
Bagre marina
Galeichthys felis
Paralichthys lethostigma
Syacium gunteri
Cyclopsetta chittendeni
Citharichthys spilopterus
Etropus crossotus
Achirus fasciatus
Achirus lineatus
Symphurus plagiusa
Sphyraena guachancho
Polydactylus octonemus
Scomberomorus maculatus
Trichiurus lepturus
Peprilus paru
Poronotus triacanthus
Caranx hippos
Hemicaranx amblyrhynchus
Chloroscombrus chrysurus
Vomer setapinnis
Centropristes philadelphicus
Conodon nobilis
Orthopristis chrysopterus
Stenotomus caprinus
Lagodon rhomboides
Eucinostomus gula
Larimus fasciatus
Stellifer lanceolatus
Leiostomus xanthurus
Micropogon undulatus
Menticirrhus americanus
Menticirrhus focaliger
Cynoscion arenarius
Cynoscion nothus
Chaetodipterus faber
Chilomycterus schoepfi

The most abundant families of fish were Sciaenidae, Ariidae, Otolithidae, Trichiuridae, Carangidae, Achiridae and Bothidae. The most abundant species of fish were gafftopsail, *Bagre marina*, sand trout, *Cynoscion arenarius*, the whiting, *M. americanus*, the cutlass fish, *Trichiurus lepturus*, and the common croaker, *Micropogon undulatus*. At the onset of cold weather shrimp and some species of fish migrate from the bays to the offshore waters of the Gulf. Gunter (1945 and 1950) has presented data on the seasonal movements of shrimp and fish to and from the Texas bays. It is easy to see why the gafftopsail, *Bagre marina*, the cutlass fish, *Trichiurus lepturus*, and the sand trout, *C. arenarius*, would be common among the migrating shrimp, as these fish feed at least in part on shrimp. The common croaker, as Gunter (1936, 1945) has shown, is the most abundant fish in the shallow water of the bays and Gulf. As both shrimp and croakers feed on benthic organisms, they may compete for food.

Several methods of classification can be used for the less abundant fish. A few fish such as the porgy, *S. caprinus*, Gunter's flounder, *S. gunteri*, Mexican flounder, *Cyclopsetta chittendeni*, rock bass, *Centropristes philadelphicus*, butterfish, *P. triacanthus*, and the Texas skate, *R. texana*, are common in deeper water, but very few appeared in the trawl catches of white shrimp. Some fish are pelagic and the gear used was not suitable for catching them. The principal pelagic fishes were the Gulf sardine, *H. pensacolae*, the menhaden, *B. patronus*, the Spanish mackerel, *S. maculatus*, the jackfish, *C. hippos*, and the anchovies, *Anchoa* spp. Still other fish such as the guachanche, *S. guachancho*, the porcupine fish, *C. schoepfi*, the barred grunt, *C. nobilis*, and the mink fish, *M. focaliger*, evidently are not abundant anywhere in the northwestern Gulf. The remaining species of fish on the list are not uncommon in the northern Gulf but they did not approach the abundance of the first five species.

Generally, most trawlers have migrated to the brown shrimp grounds by the first of December and only sporadic attempts to locate white shrimp are made during the rest of the winter. A single drag, 2 hours and 45 minutes long, was completed in 10 to 11 fathoms off Pass Cavallo on December 11, 1951, and this drag represents the sole attempt to find white shrimp during the winter months by any boat which I was aboard. An estimated 93 acres of bottom were swept. Table 9 shows the relative abundance of fish in this trawl haul.

TABLE 9

Catch of Fish in 10 to 11 Fathoms off Pass Cavallo on December 11, 1950*

Syacium gunteri	1192	Peprilus paru	16
Trichiurus lepturus	608	Nautopaedium porosissimum	8
Citharichthys spilopterus	448	Prionotus rubio	8
Synodus foetens	272	Poronotus triacanthus	8
Cynoscion nothus	216	Paralichthys lethostigma	8
Etropus crossotus	184	Raja texana	8
Menticirrhus americanus	56	Carcharhinus porosus	1
Symphurus	48	Carcharhinus leucas	1
Micropogon undulatus	40	Caranx hippos	1
Cyclopsetta chitttendeni	32	Scomberomorus maculatus	1
Chaetodipterus faber	32		

* For explanation see text.

A total of 3,188 fish was counted. These fish are distributed among 21 species belonging to 14 families. Perhaps the most noteworthy feature of this drag is the large number of cutlass fish, *T. lepturus*, and the spotfin whiff, *C. spilopterus*, because no larger hourly catches were observed during the winter months.

Sabine, Texas

Approximately a third of the fish counted during this investigation were caught during 11 hours and ten minutes of trawling off Sabine Pass, Texas. Yet, the time spent trawling represents only about 3.5 per cent of the 315 hours and 10 minutes of recorded trawl catches. An estimated 300 acres were swept by the trawl. In Table 10 rare species from three other drags that were not recorded numerically are also included. Perhaps it should again be stated that all drags completed during this investigation were recorded as to species present, but numerical data were not gathered from all drags.

TABLE 10

Catch of Fish During June off Sabine, Texas in 6–7 Fathoms*

Micropogon undulatus	58,500	Ogcocephalus cubifrons	23
Polydactylus octonemus	28,800	Pteroplatea micrura	16
Trichiurus lepturus	24,900	Opisthonema oglinum	12
Cynoscion nothus	6,550	Pomatomus saltatrix	12
Cynoscion arenarius	1,550	Anchoa hepsetus	10
Poronotus triacanthus	1,386	Citharichthys spilopterus	10
Centropristes philadelphicus	1,085	Paralichthys lethostigma	6
Galeichthys felis	975	Achirus fasciatus	4
Larimus fasciatus	675	Nautopaedium porosissimum	3
Vomer setapinnis	480	Dasyatis sabina	3
Menticirrhus americanus	430	Brevoortia patronus	2
Chloroscombrus chrysurus	290	Hippocampus hudsonius	2
Anchoa mitchilli diaphana	270	Syngnathus louisianae	2
Prionotus rubio	250	Narcine brasiliensis	2
Chaetodipterus faber	135	Aprionodon isodon	2
Leiostomus xanthurus	75	Ophichthys gomesi	1
Prionotus tribulus	50	Dasyatis sayi	1
Peprilus paru	26	Rhinobatus lentiginosus	1

* See text for further explanation.

Thirty-six species of fish, belonging to 24 families, were caught. Forty-eight per cent of the fishes caught belong to the Family Sciaenidae and four families, Sciaenidae, Polynomidae, Trichiuridae and Otolithidae, contained 90 per cent of the fishes.

Such species as *P. triacanthus*, *C. philadelphicus* and *P. rubio* are represented by small, young fish. All croakers were small and they were probably at the end of their first year of life.

It should be particularly noted that the large catch of fish was made after spending more hours scouting than fishing for shrimp. One important object of the scouting was to locate grounds relatively free of large numbers of croakers. No trawling was done if more than three or four croakers were caught per 15-minute trynet haul.

Southwest Pass Grounds

Since only a few drags were completed in this area, it has been found most convenient to group all drags. Twelve hours and 35 minutes were spent trawling in depths of 12 to 13 fathoms, while the net was dragged only seven hours and ten minutes in 19 to 24 fathoms. Moreover, nearly all the trawling in 12 to 13 fathoms was done during the day, while the deeper water trawling was at night. Five of the six drags were recorded numerically. In the sixth drag only the rare fish were counted and these counts are included in Table 11.

TABLE 11

Relative Abundance of Fishes on the Southwest Pass Grounds During June

Prionotus rubio	10,400	Ancylopsetta quadrocellata	30*
Micropogon undulatus	7,400	Lutianus blackfordi	26*
Trichiurus lepturus	4,000	Trachurus lathami	25*
Syacium gunteri	3,120	Lactophrys tricornis	14*
Centropristes philadelphicus	2,075	Upeneus parvus	14*
Cyclopsetta chittendeni	1,925	Lepophidium brevibarbe	13*
Synodus spp.	1,025	Symphurus sp.	12*
Vomer setapinnis	935	Scoliodon terrae-novae	12*
Leiostomus xanthurus	700	Harengula p. pensacolae	12*
Cynoscion nothus	700	Hoplunnis macrurus	10*
Cynoscion arenarius	595	Otophidium welshi	8*
Poronotus triacanthus	550	Halieutichthys aculeatus	6*
Larimus fasciatus	545	Lutianus synagris	6*
Citharichthys spilopterus	530	Stenotomus caprinus	6*
Eucinostomus gula	225	Citharichthys macrops	5*
Paracentropristes pomospilus	200	Lagocephalus laevigatus	5*
Paralichthys lethostigma	198	Achirus fasciatus	3*
Menticirrhus americanus	195	Pteroplatea micrura	3*
Etropus crossotus	155	Balistes capriscus	3*
Prionotus tribulus	50	Urophycis floridana	2*
Nautopaedium porosissimum	50	Monacanthus hispidus	2*
Anchoa hepsetus	45	Ogcocephalus sp.	2*
Raja texana	67*	Gymnachirus texae	1*
Scorpaena calcarata	52*	Peprilus paru	1*

* All six drags are included in counts.

Five drags lasting sixteen hours and ten minutes produced approximately 35,900 fish. An estimated 540 acres were swept by the shrimp trawl during these five drags. Forty-eight species belonging to 30 families were caught. The first ten families listed in order of abundance are Triglidae, Sciaenidae, Bothidae, Trichiuridae, Serranidae, Otolithidae, Synodontidae, Carangidae, Stromateidae and Gerridae.

The most striking feature was the abundance of sea robins, *P. rubio*, a fish which was not found to be the dominant element anywhere else in the Gulf. It seems to prefer soft mud off the mouths of rivers, and in Louisiana *P. rubio* was decidedly more abundant in 19 to 24 fathoms than in the shallower depths.

Texas Grounds (North of the Latitude of Aransas Pass)

Thirty hours and fifty-five minutes were spent trawling from Aransas Pass to Matagorda Island between October 20 to 25, 1950. The species encountered were recorded, but only a few notes on relative abundance were entered in my field log. The species of fish are listed systematically in Table 12.

Fifty-six species were recorded in the 12 to 18 fathom zone as compared to 45 species in 3–8 fathoms of water in the same general region. The five most abundant families of fishes were Sciaenidae, Bothidae, Otolithidae, Sparidae and Triglidae.

During December, the shrimping grounds north of Aransas Pass were visited twice. The first trip was along St. Joseph and Matagorda Islands in 15 to 20 fathoms of water. Forty-four hours and forty-five minutes were spent trawling for brown shrimp, and an estimated 1,480 acres of bottom were swept by the trawls.

The computed count was 27,230 fish. These fishes are distributed among 52 species and 24 families. The five most abundant families were Bothidae, Serranidae, Synodontidae, Otolithidae and Sciaenidae.

TABLE 12

Species of Fish Caught in 12–18 Fathoms on the Northern Half of the Texas Grounds During October*

Sphyrna tiburo	Paracentropristes pomospilus
Rhinobatus lentiginosus	Lutianus synagris
Raja texana	Lutianus blackfordi
Dasyatis sayi	Conodon nobilis
Pteroplatea micrura	Orthopristis chrysopterus
Anchoa hepsetus	Stenotomus caprinus
Congrina flava	Lagodon rhomboides
Neoconger mucronatus	Eucinostomus spp.
Synodus foetens	Upeneus parvus
Paralichthys spp.	Larimus fasciatus
Ancylopsetta quadrocellata	Stellifer lanceolatus
Syacium gunteri	Leiostomus xanthurus
Cyclopsetta chittendeni	Micropogon undulatus
Citharichthys spilopterus	Menticirrhus americanus
Citharichthys macrops	Cynoscion arenarius
Etropus crossotus	Cynoscion nothus
Gymnachirus texae	Chaetodipterus faber
Symphurus spp.	Prionotus rubio
Polydactylus octonemus	Lepophidium brevibarbe
Scomberomorus maculatus	Nautopaedium porosissimum
Trichiurus lepturus	Balistes capriscus
Peprilus paru	Alutera schoepfi
Poronotus triacanthus	Lactophrys tricornis
Caranx hippos	Lagocephalus laevigatus
Chloroscombrus chrysurus	Sphoeroides nephelus
Vomer setapinnis	Chilomycterus schoepfi
Diplectrum arcuarium	Ogcocephalus sp.
Centropristes philadelphicus	Halieutichthys aculeatus

* For further explanation see text.

TABLE 13

Relative Abundance of Fish on the Northern Texas Grounds During Early December

Syacium gunteri	11,649	Hoplunnis macrurus	66
Synodus spp.*	2,838	Symphurus spp.†	43
Cyclopsetta chittendeni	2,409	Peprilus paru	33
Paracentropristes pomospilus	1,607	Leiostomus xanthurus	24
Diplectrum arcuarium	1,536	Balistes capriscus	24
Prionotus rubio	1,110	Bollmannia communis	21
Cynoscion nothus	1,053	Prionotus ophryas	17
Cynoscion arenarius	641	Brevoortia patronus	14
Centropristes philadelphicus	524	Lactophrys tricornis	13
Micropogon undulatus	451	Lutianus blackfordi	12
Chaetodipterus faber	416	Lagodon rhomboides	7
Ogcocephalus sp.	405	Gymnothorax nigromarginatus	7
Stenotomus caprinus	385	Scomberomorus maculatus	4
Citharichthys spilopterus	339	Carcharhinus limbatus	3
Nautopaedium porosissimum	301	Prionotus stearnsi	3
Engyophrys sentus	293	Sphyrna tiburo	2
Lepophidium brevibarbe	202	Lutianus synagris	2
Raja texana	159	Carcharhinus porosus	2
Trichiurus lepturus	148	Prionotus scitulus	1
Gymnachirus texae	136	Trachinotus carolinus	1
Poronotus triacanthus	135	Congrina flava	1
Menticirrhus americanus	135	Dasyatis sayi	1
Paralichthys sp.	121	Sphyrna tudes	1
Sphoeroides nephelus	111	Mustelus canis	1
Eucinostomus spp.	73	Pomatomus saltatrix	1

* Includes both *S. foetens* and *S. poeyi*.
† Only *S. civitatum* was found in the collection made.

On the second trip during December, 1950 a small area south of Greens Bayou in 18 to 25 fathoms was fished. An estimated 550 acres were trawled during 16 hours and 20 minutes of fishing.

TABLE 14

The Relative Abundance of Fishes in 18 to 25 Fathoms Off Greens Bayou During December

Syacium gunteri	5,080	Lepophidium brevibarbe	56
Cyclopsetta chittendeni	2,815	Bagre marina	40
Synodus sp.	1,895	Gymnachirus texae	33
Prionotus rubio	1,115	Cynoscion nothus	26
Centropristes philadelphicus	750	Poronotus triacanthus	21
Stenotomus caprinus	680	Upeneus parvus	20
Diplectrum arcuarium	646	Ancylopsetta quadrocellata	20
Paracentropristes pomospilus	520	Scorpaena calcarata	17
Ogcocephalus sp.	256	Lutianus blackfordi	14
Paralichthys	137	Symphurus sp.	15
Micropogon undulatus	125	Balistes capriscus	9
Cynoscion arenarius	100	Bollmannia communis	5
Sphoeroides nephelus	111	Eucinostomus	4
Chaetodipterus faber	91	Lactophrys tricornis	3
Raja texana	75	Dasyatis sayi	2
Engyophrys sentus	71	Gobionellus gracillimus	1
Nautopaedium porosissismum	60	Pristipomoides andersoni	1
Leiostomus xanthurus	56	Gymnothorax nigromarginatus	1
Menticirrhus americanus	56	Squatina dumerili	1

The computed tally of fishes was 14,750. The five most abundant families were Bothidae, Serranidae, Synodontidae, Triglidae and Sparidae. In all 38 species of fishes belonging to 25 families were recorded.

One noteworthy feature of this trip was the appearance of the gaff-topsail catfish, *B. marina*, in depths greater than 20 fathoms. The crew reported that during the preceding week gaff-topsails were quite abundant at 24 fathoms.

Two drags completed during May, 1951 end the investigation of the north Texas grounds. Voracious sharks tore gaping holes in one net, so only a single drag was saved. However, a few fish were still retained in the webbing of the shark damaged net and they are recorded in Table 15. The location of the completed drag was in 18 fathoms of water southeast of Matagorda. The net was lifted after four hours and 40 minutes of trawling on May 6, 1951. Approximately 112 acres of bottom were fished with the 96-foot trawl.

TABLE 15

Relative Abundance of Fishes in 18 Fathoms Southeast of Matagorda, Texas During May

Stenotomus caprinus	2,150	Gymnachirus texae	5
Syacium gunteri	950	Nautopaedium porosissimum	5
Cynoscion nothus	480	Balistes capriscus	5
Cyclopsetta chittendeni	225	Paralichthys spp.	5
Synodus spp.	175	Vomer setapinnis	5
Centropristes philadelphicus	125	Chaetodipterus faber	5
Urophycis floridanus	75	Lactophrys tricornis	3
Prionotus rubio	50	Scorpaena calcarata	2
Sphoeroides nephelus	25	Lutianus synagris	2
Ogcocephalus sp.	25	Pristipomoides andersoni	2
Prionotus paralatus	25	Micropogon undulatus	2
Cynoscion arenarius	25	Squatina dumerili	2
Lepophidium brevibarbe	10	Pteroplatea micrura	3
Diplectrum arcuarium	10	Prionotus stearnsi	1
Paracentropristes pomospilus	10	Halieutichthys aculeatus	1
Symphurus spp.	9	Selar crumenophthalmus	1
Raja texana	8		

The total count was 4,430 fish. These fish belong to 34 species and 24 families. The five most abundant families were Sparidae, Bothidae, Otolithidae, Synodontidae and Serranidae.

Especially noteworthy was the abundance of the porgy, *S. caprinus*. A few days later while trawling nearly 100 miles to the south in comparable depths only a few porgies were found, but the butterfish, *P. triacanthus*, abounded.

Texas Grounds (South of the latitude of Aransas Pass)

The first trip to the southern part of the Texas grounds was made during November. Elapsed fishing time was 36 hours and 45 minutes, but due to the number of mishaps only 20 hours and 50 minutes were spent fishing with undamaged nets. Rare fish from all drags are entered in Table 16.

TABLE 16

Relative Abundance of Fishes in 17–19 Fathoms on the Southern Texas Grounds During November

Syacium gunteri	4,951	Polydactylus octonemus	30
Cynoscion	3,378	Lepophidium brevibarbe	30
Cyclopsetta chittendeni	918	Paralichthys	24
Synodus spp.	511	Engyophrys sentus	18
Prionotus rubio	556	Scorpaena calcarata	18
Trichiurus lepturus	397	Bagre marina	14
Paracentropristes pomospilus	374	Gymnachirus texae	12
Diplectrum arcuarium	370	Bollmannia communis	8
Chaetodipterus faber	340	Lutianus blackfordi	7
Stenotomus caprinus	335	Lactophrys tricornis	7
Vomer setapinnis	259	Chilomycterus schoepfi	6
Micropogon undulatus	200	Echeneis naucrates	6
Centropristes philadelphicus	180	Galeichthys felis	4
Citharichthys spilopterus	112	Pteroplatea micrura	3
Leiostomus xanthurus	133	Gymnothorax nigromarginatus	2
Menticirrhus americanus	111	Priacanthus arenatus	2
Chloroscombrus chrysurus	87	Caranx hippos	2
Poronotus triacanthus	86	Sphyrna tiburo	2
Ogcocephalus	77	Ancylopsetta quadrocellata	1
Eucinostomus	71	Lonchopisthes lindneri	1
Symphurus	71	Lutianus synagris	1
Nautopaedium porosissimum	32	Prionotus pectoralis	1
Lagocephalus laevigatus	32	Congrina flava	1
Halieutichthys aculeatus	31	Hoplunnis macrurus	1
Balistes capriscus	29	Harengula p. pensacolae	1
Sphoeroides nephelus	22	Pristis pectinatus	1
Anchoa hepsetus	53*	Narcine brasiliensis	1
Peprilus paru	33		

* Entire catch recorded from all November drags.

Approximately 13,120 fish were caught. Fifty-six species of fish, belonging to 32 families are represented in the catch. The five most abundant families were Bothidae, Otolithidae, Serranidae, Synodontidae and Sciaenidae.

Except for a few drags during July when shrimp were very abundant, there were less trash fish and invertebrates caught in these drags. The captain set the "jumper chain" to eliminate the maximum amount of "trash."

Two trips were made to the Texas grounds during January. I traveled on the large refrigerated trawler, "Sabine No. 1" during the first of January. Five drags out of six were successfully completed. A few rare fish from the sixth drag are also entered in Table 17. During the five drags, 21 hours and 25 minutes were spent dragging an estimated 810 acres of bottom.

TABLE 17

Relative Abundance of Fishes on the Southern Texas Grounds in 17 to 24 Fathoms During Early January

Syacium gunteri	2,333	Gymnachirus texae	28
Cyclopsetta chittendeni	1,985	Sphoeroides nephelus	24
Paracentropristes pomospilus	1,385	Cynoscion nothus	16
Centropristes philadelphicus	1,085	Scomberomorus maculatus	14
Stenotomus caprinus	1,104	Prionotus stearnsi	10
Synodus*	564	Peprilus paru	6
Prionotus rubio	484	Lactophrys tricornis	6
Cynoscion arenarius	415	Balistes capriscus	6
Diplectrum arcuarium	305	Halieutichthys aculeatus	5
Nautopaedium porosissimum	228	Ancylopsetta quadrocellata	5
Engyophrys sentus	171	Lutianus blackfordi	4
Ogcocephalus sp.	145	Lutianus synagris	3
Chaetodipterus faber	115	Prionotus ophryas	3
Bollmannia communis	110	Symphurus	3
Lepophidium brevibarbe	91	Brevoortia patronus	1
Micropogon undulatus	73	Sphyrna tiburo	1
Trichiurus lepturus	71	Dasyatis sayi	1
Menticirrhus americanus	65	Hoplunnis macrurus	2
Raja texana	42	Kathetostoma albigutta	1
Bagre marina	41	Poronotus triacanthus	1
Eucinostomus sp.	72	Vomer setapinnis	1
Paralichthys	31		

* S. foetens and S. poeyi.

An estimated total of eleven thousand fish was recorded. Forty-four species belonging to 29 families are included in the catch. The five most abundant families were Bothidae, Serranidae, Sparidae, Synodontidae and Triglidae.

Perhaps the rarity of sand trout is the most noteworthy feature of the catch. A few species such as *Bagre marina* and *Micropogon undulatus* are winter migrants from the more shallow water of the Gulf. The catching of Spanish mackerel and menhaden shows that there is a winter population of unknown size offshore from the Texas coast.

The second trip during January was a very brief one to the grounds off Corpus Christi Pass. Only three drags were completed; the fourth drag was lost through a large rip in the cod-end. Several rare fish were still retained by the webbing and they are entered in Table 18. Twelve hours and twenty minutes were spent trawling about 415 acres.

TABLE 18

Relative Abundance of Fishes off Corpus Christi Pass in 18–24 Fathoms of Water During Late January

Syacium gunteri	2,294	Lutianus blackfordi	15
Cyclopsetta chittendeni	690	Raja texana	12
Synodus*	664	Paralichthys sp.	12
Diplectrum arcuarium	530	Scomberomorus maculatus	12
Paracentropristes pomospilus	310	Poronotus triacanthus	11
Centropristes philadelphicus	203	Stenotomus caprinus	9
Cynoscion arenarius	166	Menticirrhus americanus	8
Prionotus rubio	156	Prionotus ophryas	4
Bagre marina	96	Gymnachirus texae	3
Engyophrys sentus	48	Eucinostomus sp.	2
Ogcocephalus	44	Balistes capriscus	2
Galeichthys felis	48	Prionotus stearnsi	2
Cynoscion nothus	32	Mystriophis intertinctus	1
Bollmannia communis	36	Gymnothorax nigromarginatus	1
Nautopaedium porosissimum	27	Bregmaceros atlanticus	1
Sphoeroides nephelus	24	Trachinotus carolinus	1
Lepophidium brevibarbe	24	Trichiurus lepturus	1
Chaetodipterus faber	20	Lagodon rhomboides	1
Micropogon undulatus	16		

* S. foetens and S. poeyi.

A total of five thousand five hundred and ten fish was counted. Thirty-seven species divided among 26 families are represented. The five most abundant families were Bothidae, Serranidae, Synodontidae, Ariidae and Otolithidae.

Two drags were completed during March in 24 fathoms of water north northeast of Brazos Santiago. An unusual feature of this area was the large concentration of sand dollars, *Clypeaster ravenelli.* One of the two drags was counted, but the rare fish from the remaining drag are entered in Table 19. Six hours were spent trawling and 203 acres of bottom were swept.

TABLE 19

Relative Abundance of Fishes in 24 Fathoms North Northeast of Brazos Santiago During March

Stenotomus caprinus	2,280	Eucinostomus*	20
Syacium gunteri	2,040	Poronotus triacanthus	10
Synodus sp.	540	Diplectrum arcuarium	10
Cyclopsetta chittendeni	540	Micropogon undulatus	10
Cynoscion nothus	360	Prionotus paralatus	10
Paracentropristes pomospilus	240	Trichiurus lepturus	4
Engyophrys sentus	180	Paralichthys lethostigma	6
Cynoscion arenarius	180	Carcharhinus porosus	4
Nautopaedium porosissimum	180	Uroconger sp.	2
Centropristes philadelphicus	120	Hoplunnis macrurus	2
Prionotus rubio	120	Monacanthus hispidus	1
Ogcocephalus	60	Sphoeroides spengleri	1
Chaetodipterus faber	60	Balistes capriscus	1
Raja texana	20	Pristipomoides andersoni	1
Prionotus stearnsi	20	Congrina flava	1
Menticirrhus americanus	20	Dasyatis sayi	1
Lepophidium brevibarbe	20	Mustelus canis	1

* E. gula and E. argentus.

An estimated total of 6,490 fish were caught. The increased number of fish may be in part due to sand dollars blocking the meshes, and thereby preventing the escape of small fish. Thirty-six species of fishes belonging to 20 families are listed. The five most abundant families are Bothidae, Sparidae, Otolithidae, Synodontidae and Serranidae.

The April trip was a brief one to the Texas grounds. All trawling was done off Mustang Island in 18 to 22 fathoms. Four hours and ten minutes were spent trawling and an estimated 120 acres of bottom were swept. The sharks emptied the cod-end of the remaining haul.

TABLE 20

Relative Abundance of Fishes off Mustang Island During April

Stenotomus caprinus	925	Nautopaedium porosissimum	25
Syacium gunteri	575	Ogcocephalus	25
Engyophrys sentus	225	Lagodon rhomboides	20
Paracentropristes pomospilus	200	Raja texana	18
Cyclopsetta chittendeni	175	Ancylopsetta quadrocellata	9
Centropristes philadelphicus	100	Vomer setapinnis	4
Cynoscion nothus	100	Menticirrhus americanus	5
Synodus	100	Lactophrys tricornis	3
Lepophidium brevibarbe	100	Monacanthus hispidus	2
Bollmannia communis	50	Trichopsetta ventralis	1
Sphoeroides nephelus	50	Hippocampus hudsonius	1
Cynoscion arenarius	50	Mustelus canis	1
Prionotus rubio	25		

An estimated 2,790 fish were caught. The catch includes 25 species belonging to 22 families. The five most abundant families were Bothidae, Sparidae, Serranidae, Otolithidae and Synodontidae.

Extensive trawling was done in May on the Texas grounds. Fourteen drags out of 18 completed were counted. A total of 69 hours and 50 minutes was spent trawling and an estimated 1,876 acres were swept. Trawling was done between the 17 to 22 fathom contours. In Table 21 40,420 fish are listed. They represent 61 species belonging to

TABLE 21

Relative Abundance of Fishes on the South Texas Grounds Between the 17 to 22 Fathom Contours During May

Poronotus triacanthus	22,270	Hoplunnis macrurus	22
Syacium gunteri	3,805	Menticirrhus americanus	20
Cynoscion nothus	3,675	Micropogon undulatus	18
Cyclopsetta chittendeni	1,995	Larimus fasciatus	17
Cynoscion arenarius	1,425	Peprilus paru	15
Synodus sp.*	1,410	Mustelus canis	10
Trichiurus lepturus	1,305	Lagocephalus laevigatus	9
Centropristes philadelphicus	560	Carcharhinus obscurus	7
Engyophrys sentus	510	Lagodon rhomboides	7
Vomer setapinnis	412	Lutianus synagris	7
Paracentropristes pomospilus	300	Trichiurus lathami	6
Prionotus rubio	300	Etropus crossotus	6
Urophycis floridanus	235	Scomber colias	6
Antennarius radiosus	198	Symphurus sp.	6
Diplectrum arcuarium	185	Sphoeroides nephelus	5
Raja texana	160	Chloroscombrus chrysurus	5
Prionotus stearnsi	158	Pteroplatea micrura	3
Chaetodipterus faber	141	Lactophrys tricornis	3
Trichopsetta ventralis	132	Halieutichthys aculeatus	2
Citharichtys spilopterus	90	Stenotomus caprinus	2
Nautopaedium porosissimum	76	Chilomycterus schoepfi	1
Prionotus pectoralis	76	Anchoa m. diaphana	1
Ogcocephalus sp.	60†	Anchoa hepsetus	1
Lepophidium brevibarbe	55	Carcharhinus milberti	1
Prionotus paralatus	57	Gymnothorax nigromarginatus	1
Paralichthys sp.	40	Fistularia tabacaria	1
Lutianus blackfordi	35	Promicrops itaiara	1
Prionotus ophryas	32	Bathystoma a. rimator	1
Pristipomoides andersoni	32	Gobionellus gracillimus	1
Upeneus parvus	22	Balistes capriscus	1
Ancylopsetta quadrocellata	22		

* S. poeyi and S. foetens.
† All species that were caught less than 60 times include fish counts from 18 instead of 14 drags.

31 families. The first most abundant families are Stromateidae, Bothidae, Otolithidae, Synodontidae and Trichiuridae.

A very striking feature of these drags is the great abundance of the butterfish, *Poronotus triacanthus*. Gunter (1938 and 1945) found increased abundance of this fish in the bay and shallow Gulf waters of Texas and Louisiana during March. Butterfish were much more common in day drags than at night.

During July extensive trawling was prosecuted off Padre Island in 12 to 18 fathoms of water. Counts of fish were made in 10 of the 21 drags completed. In the remaining drags only counts of the rare species were listed. An estimated 980 acres of bottom were swept during 38 hours and 30 minutes of trawling.

TABLE 22

The Relative Abundance of Fishes on the South Texas Grounds During July

Poronotus triacanthus	17,330	Polydactylus octonemus	25
Syacium gunteri	16,175	Lutianus blackfordi	22
Micropogon undulatus	1,865	Ogcocephalus sp.	20
Cyclopsetta chittendeni	1,575	Bollmannia communis	20
Cynoscion nothus	1,495	Leiostomus xanthurus	15
Synodus foetens	975	Prionotus ophryas	13
Citharichthys spilopterus	745	Gymnothorax nigromarginatus	12
Menticirrhus americanus	837	Sphoeroides nephelus	10
Prionotus rubio	620	Pristipomoides andersoni	10
Cynoscion arenarius	606	Lactophrys tricornis	10
Diplectrum arcuarium	555	Sphyraena guachancho	10
Etropus crossotus	535	Balistes capriscus	9
Lagocephalus laevigatus	430	Scomber colias	9
Trichiurus lepturus	375	Syngnathus louisianae	8
Centropristes philadelphicus	330	Urophycis floridanus	8
Vomer setapinnis	321	Ancylopsetta quadrocellata	7
Nautopaedium porosissimum	288	Chilomycterus schoepfi	6
Symphurus sp.	275	Peprilus paru	5
Prionotus pectoralis	256	Congrina flava	3
Prionotus paralatus	215	Antennarius radiosus	3
Paracentropristes pomospilus	164	Monacanthus hispidus	2
Stenotomus caprinus	164	Priacanthus arenatus	2
Engyophrys sentus	153	Eucinostomus gula	2
Larimus fasciatus	140	Prionotus tribulus	1
Harengula pensacolae	126	Caulolatilus cyanops	1
Prionotus stearnsi	123	Lagodon rhomboides	1
Raja texana	119	Serraniculus pumilio	1
Galeichthys felis	112	Narcine brasiliensis	1
Gymnachirus texae	92	Antennarius scaber	1
Brotula barbata	39	Pteroplatea micrura	1
Hoplunnis macrurus	35	Uroconger sp.	1
Upeneus parvus	29	Paralichthys albigutta	1
Lepophidium brevibarbe	29	Seriola dumerili	1
Paralichthys sp.	27	Rhomboplites aurorubens	1
Anchoa hepsetus	26		

Approximately 46,970 fish are listed. They represent 69 species or 39 families. The five most abundant families are Bothidae, Stromateidae, Sciaenidae, Otolithidae and Triglidae.

24–10 Grounds

Fish were counted in 8 drags out of 14, but the rare fish in the remaining six drags are listed in Table 23. Thirty-seven hours and fifteen minutes were spent trawling 1,348 acres. While some fishing was done in depths of 21–45 fathoms, most of the trawling was done in depths of 32–37 fathoms. No comparative data for other seasons of the year are available.

Approximately 14,570 fish were counted. They belong to 71 species and 40 families. The five most abundant families were Bothidae, Otolithidae Synodontidae, Serranidae and Sparidae.

Execestides egregius, *Raja olseni*, *Ancylopsetta dilecta* and *Scorpaena dispar* are strays from deeper water. *C. faber*, *T. lepturus*, *L. xanthurus*, *B. marina* and *N. brasiliensis* are winter migrants from shallower water.

Obregon

All fish were counted in 11 drags out of 32. Only the rare fish from the remaining 21 drags are listed in Table 24. The trawl was dragged 24 hours and 50 minutes. An

estimated 838 acres were trawled. The depths ranged from 14 to 20 fathoms and all trawling was at night.

TABLE 23

Relative Abundance of Fishes on the 24–10 Grounds During March

Syacium gunteri	7,800	Lutianus blackfordi	28*
Cynoscion nothus	3,836	Sphoeroides nephelus	24*
Synodus sp.	2,194	Bollmannia communis	20*
Cyclopsetta chittendeni	1,755	Pristipomoides andersoni	15*
Stenotomus caprinus	1,734	Pteroplatea micrura	14*
Paracentropristes pomospilus	1,245	Hoplunnis macrurus	12*
Centropristes philadelphicus	706	Scorpaena dispar	11*
Menticirrhus americanus	382	Antennarius radiosus	9*
Prionotus rubio	369	Narcine brasiliensis	8*
Trichopsetta ventralis	348	Bagre marina	8*
Chaetodipterus faber	339	Peprilus paru	7*
Engyophrys sentus	300	Gymnothorax nigromarginatus	6*
Trichiurus lepturus	250	Antennarius scaber	6*
Scorpaena calcarata	245	Larimus fasciatus	5*
Cynoscion arenarius	240	Sphoeroides dorsalis	4*
Lepophidium brevibarbe	172	Dysomma aphododera	3*
Lagodon rhomboides	184	Symphurus pelicanus	3*
Poronotus triacanthus	149	Sphyrna diplana	2*
Gymnachirus texae	131	Squatina dumerili	2*
Nautopaedium porosissimum	130	Trachurus lathami	2*
Eucinostomus sp.	129	Mustelus canis	1*
Ogcocephalus sp.	101	Carcharhinus obscurus	1*
Kathetostoma albigutta	99	Raja olseni	1*
Chloroscombrus chrysurus	200*	Congrina flava	1*
Prionotus ophryas	60	Bregmaceros atlanticus	1*
Prionotus stearnsi	60	Urophycis floridanus	1*
Upeneus parvus	60	Ancylopsetta quadrocellata	1*
Halieutichthys aculeatus	50	Ancylopsetta dilecta	1*
Bellator militaris	50	Paralichthys lethostigma	1*
Raja texana	46*	Rachycentron canadus	1*
Balistes capriscus	23*	Eques acuminatus	1*
Diplectrum arcuarium	85*	Leiostomus xanthurus	1*
Prionotus paralatus	50*	Execestides egregius	1*
Lagocephalus laevigatus	36*	Monacanthus hispidus	1*
Vomer setapinnis	26*	Rissola?	1*
Micropogon undulatus	29*	Brotula barbata	1*

* All 12 drags are included in count.

The fish tally was 58,880. Forty-five families and 86 species of fish were represented in the catch. The five most abundant families were Serranidae, Batrachoididae, Synodontidae, Bothidae and Triglidae.

Although it would be presumptuous to compare absolute numbers of fish caught on the Obregon grounds with those caught during July on the Texas grounds, there are a number of differences in relative numbers which should be stressed. The most striking difference is the great abundance of butterfish, *P. triacanthus*, off Padre Island and its rarity on the Obregon grounds. Butterfish are pelagic at times, and some of the difference may be explained by two daytime drags off Padre Island and none off Obregon. Another major difference was the much greater abundance of the midshipmen, *N. porosissimum*, and the cusk eel, *Lepophidium brevibarbe*, on the Obregon grounds. Flatfish were more common on the Padre Island ground, but how much of the difference in numbers should be ascribed to difference in gear is not known. The absence of the batfish, *Ogcocephalus*, sea bass, *Centropristes philadelphicus*, and the rarity of *Cynoscion nothus* was unex-

TABLE 24

Relative Abundance of Fishes on the Obregon Grounds During July and Early August

Paracentropristes pomospilus	20,000	Pristipomoides andersoni	14*
Nautopaedium porosissimum	10,000	Harengula pensacolae	14*
Synodus sp.	5,300	Alutera ventralis	12*
Syacium gunteri	4,300	Dysomma aphododera	12*
Lepophidium brevibarbe	3,000	Anchoa hepsetus	11*
Prionotus rubio	2,100	Trachinocephalus myops	10*
Diplectrum arcuarium	1,200	Pteroplatea micrura	9*
Trichiurus lepturus	1,100	Priacanthus arenatus	8*
Cyclopsetta chittendeni	775	Prionotus tribulus	8*
Cynoscion arenarius	760	Caulolatilus cyanops	5*
Prionotus stearnsi	645	Lutianus synagris	5*
Eucinostomus gula	580	Conodon nobilis	5*
Polydactylus octonemus	569	Umbrina coroides	5*
Vomer setapinnis	470	Larimus fasciatus	5*
Gymnachirus texae	441	Balistes capriscus	5*
Stenotomus caprinus	410	Gymnothorax nigromarginatus	4*
Scorpaena calcarata	401	Trachurus lathami	4*
Bellator militaris	351	Peprilus paru	4*
Halieutichthys aculeatus	270	Prionotus pectoralis	4*
Bollmannia communis	260	Promicrops itaiara	4*
Lutianus blackfordi	216	Diplectrum formosum	3*
Poronotus triacanthus	155	Carcharhinus acronotus	3*
Sphoeroides nephelus	143	Sphoeroides dorsalis	3*
Micropogon undulatus	140	Echeneis naucrates	2*
Brotula barbata	116	Monacanthus hispidus	2*
Raja texana	67	Congrina flava	2*
Symphurus sp.	67	Sphyrna diplana	2*
Lagocephalus laevigatus	55	Carcharhinus porosus	2*
Engyophrys sentus	53	Citharichthys spilopterus	1*
Cynoscion nothus	41	Dasyatis sayi	1*
Menticirrhus americanus	40	Ancylopsetta quadrocellata	1*
Upeneus parvus	25	Dactylopterus volitans	1*
Sphyraena guachancho	87*	Peristedion imberbe	1*
Hoplunnis macrurus	52*	Bregmaceros atlanticus	1*
Mustelus canis	50*	Chaetodipterus faber	1*
Lactophrys tricornis	47*	Eques acuminatus	1*
Prionotus ophryas	38*	Lutianus griseus	1*
Chilomycterus schoepfi	31*	Lutianus analis	1*
Diapterus rhombeus	20*	Garrupa nigrita	1*
Antennarius scaber	18*	Epinephelus niveatus	1*
Sphoeroides testudineus	19*	Rachycentron canadus	1*
Scorpaena plumieri	18*	Syngnathus louisianae	1*
Prionotus paralatus	16*	Symphurus diomedianus	1*

* All 32 drags are included in count.

pected. Batfish are common on the neighboring pink shrimp grounds and in the northern Gulf.

A few tropical fishes such as *Dactylopterus volitans, Diapterus rhombeus, Umbrina coroides, Trachinocephalus myops, Sphoeroides testudineus* and *Sardinella anchovia* were not taken in the northern Gulf. Other tropical fishes such as *Sphyraena guachancho* and *Fistularia tabacaria* were more abundant off Obregon.

One hundred and fifty-seven species of fish were caught during the entire investigation, if the pink shrimp grounds are excluded. These fish belong to 61 families. Only six species of fish, *Aprionodon isodon, Carcharhinus leucas, Opisthonema oglinum, Ophichthus gomesi, Achirus lineatus* and *Menticirrhus focaliger* were observed on the white shrimp grounds (less than 12 fathoms) and not on the brown shrimp grounds. Nevertheless it should be emphasized that all these fish except *A. lineatus* were very rare.

Three brief excursions to the white shrimp grounds did not provide enough data for an extensive comparison with previous work in Louisiana and Texas. Gunter (1945) reported trawling results for the years 1941 and 1942, while I worked in 1950 and 1951. The white shrimp fishery reached peak or near peak production during 1942, and by 1951 the fishery had declined more than 60 per cent. Other animals may have increased when the white shrimp declined, and this may be the explanation for the great abundance of croakers which I found in the Sabine district.

The white shrimp grounds off Sabine, Texas, on the basis of a few drags during June, resemble trawl catches off Barataria Bay more closely than those off Aransas Pass. This is especially true in the abundance of such fishes as *Trichiurus lepturus* and the star drum, *Stellifer lanceloatus* (see Gunter, 1945). The chief differences in the alongshore fauna at Port Isabel and Sabine, Texas seem to lie in the abundance of different species rather than in species differences. However, a few tropical fishes such as *Conodon nobilis, Abudefduf saxatilis,* and the angel fish, *Chaetodon ocellatus,* live along the south Texas coast, but they have not been reported from Sabine. A study of the fishes of the Texas jetties has not been made, but I have observed differences in the species of blennies that live among the rocks at Sabine and Port Isabel. Presumably the limiting factor is one of salinity. The transition zone is probably in the neighborhood of the mouth of the Colorado River.

Table 25 lists the twenty most abundant fishes found in shrimp trawls in 12 to 25 fathoms off the south Texas coast. If we compare this list with Gunter (1945) for the inshore waters we will note that only two species, *C. nothus* and *S. gunteri,* appear in the first ten fishes on both grounds. Six fish, *C. nothus, M. undulatus, C. arenarius, V. setapinnis, S. gunteri* and *M. americanus,* which appear in the ten most numerous fish on the white shrimp grounds are also found in the first twenty fishes on the brown shrimp grounds.

TABLE 25

The Order of Abundance of the Twenty Fishes Most Often Taken in Trawl Hauls on the White Shrimp Grounds* and Brown Shrimp Grounds in Texas are Given for Comparison†

Gulf

White Shrimp Grounds*	Brown Shrimp Grounds
Cynoscion nothus	Sycium gunteri
Micropogon undulatus	Poronotus triacanthus
Polydactylus octonemus	Cyclopsetta chittendeni
Galeichthys felis	Stenotomus caprinus
Cynoscion arenarius	Cynoscion nothus
Vomer setapinnis	Synodus foetens
Stellifer lanceolatus	Paracentropristes pomospilus
Symphurus plagiusa	Prionotus rubio
Leiostomus xanthurus	Diplectrum arcuarium
Syacium gunteri	Centropristes philadelphicus
Menticirrhus americanus	Cynoscion arenarius
Etropus crossotus	Trichiurus lepturus
Dasyatis sabina	Micropogon undulatus
Orthopristis chrysopterus	Engyophrys sentus
Anchoa mitchilli diaphana	Chaetodipterus faber
Anchoa hepsetus	Citharichthys spilopterus
Chloroscombrus chrysurus	Menticirrhus americanus
Achirus fasciatus	Nautopaedium porosissimum
Bagre marina	Vomer setapinnis
Poronotus triacanthus	Lepophidium brevibarbe

* From Gunter (1945).
† See text for further explanation.

In Table 26 the ten most abundant species on the brown shrimp grounds off Texas are given. *Syacium gunteri* appeared to be uniformly abundant on the grounds and no seasonal migration was discerned. *Stenotomus caprinus* was most abundant during the fall, winter and spring; the summer population was not located. Butterfish, *P. triacanthus,* appeared in abundance on the offshore grounds during May, while Gunter (1938) noted a spring increase in the shallower waters of the Gulf. Often the butterfish comprised as much as 90 per cent of the total catch during May. Spadefish, *C. faber,* emigrate to the offshore waters during the fall, and they migrate shoreward during the spring. *Citharichthys spilopterus* is abundant from the landward edge of the brown shrimp fishery to the bays, and it rarely strays deeper than 20 fathoms along the Texas coast.

The goby, *Bollmannia communis,* and the tongue sole, *S. civitatum,* were the most abundant species in trynet catches, but they rarely occurred in the large net. Their position in the order of abundance is uncertain; possibly, they should rank in the first ten. Obviously large mesh otter trawls are not suitable for catching active and slender fish like eels, and yet *Hoplunnis macrurus* was taken time and time again. Probably this long-snouted eel should be ranked among the twenty most abundant fish on the brown shrimp grounds in the western Gulf.

Comparisons of the number of species of fishes in the bays and Gulf present a number of difficulties. I used only shrimp trawls, while Gunter (1945) used minnow seines, trammel nets and otter trawls. Gunter obtained 119 species of fish from a group of stations extending from the Copano Bay to 10 fathoms in the Gulf of Mexico. I obtained 157 species in depths of 3 to 45 fathoms in the western Gulf. There is, however, no systematic order to my stations. Only one drag was attempted in depths greater than 37 fathoms. Moreover, my stations extend from Grand Isle, Louisiana to Obregon, Mexico, while Gunter's stations were confined to the Aransas Pass region.

Forty-two species or approximately 35 per cent of the species which Gunter collected were not taken by me. Most of these species are shallow water bay fish, as Gunter took only five species in trawls in the Gulf that I did not also find. Differences in species lists in the families Ogcocephalidae, Triglidae and Tetradontidae are based on different taxonomic treatment.

Gunter found 85 species in the narrow belt of bottom stretching from the beach to 10 fathoms, and 64 of these species were taken in shrimp trawls. I found 118 species of fish in shrimp trawls in 12 to 25 fathoms in the region between the mouth of the Colorado River and Brazos Santiago. This is an example of the increase of species with depth increase away from shore and probably also with salinity, which Gunter has mentioned before.

I took fifteen orders of fishes in trawls. These orders are ranked in Table 26 according to their numerical abundance. Gunter (1941) has discussed the advantages of the bottom as a habitat for fishes. Fishes most successfully adapted to life on the bottom or those which predominantly feed there should be most commonly caught in trawls. However, large predators will be less abundant that smaller fishes with shorter food chains. The Percomorphi were nearly three times as abundant as the Heterosomata, the next most abundant order. Moreover, the percomorphs in the littoral waters of the Gulf are differentiated into the greatest number of species. On the other hand the catfishes, although well adapted for feeding on the bottom, are represented by only two species and they are not nearly as abundant as the percomorphs. Furthermore, the catfishes are restricted to a narrow zone near shore.

The gobies and eels are so small or active that many of them escape through the meshes of the net. Although deep water gobies have been described, the group is more varied and apparently more abundant in the shallow, protected coastal waters. The eels are represented by a large number of species in Gulf waters, and a standard shrimp trawl is not adequate for this capture.

Isospondylous fishes were relatively rare in trawl catches, as is to be expected, since most of them are plankton feeders, and apparently remain higher in the water so that gear such as purse or lampara seines would be required for their capture.

TABLE 26

Order of Abundance of the Orders of Fishes Taken During This Investigation

Percomorphi	275,000	Gobiodea	800
Heterosomata	92,000	Isospondyli	600
Cataphracti	20,700	Anacanthini	400
Iniomi	18,500	Apodes	300
Jugulares	17,300	Aulostomi	56
Plectognathi	1,700	Lophobranchi	14
Pediculati	1,200	Discocephali	9
Nematognathi	1,100		

TABLE 27

The Numbers of Fish Belonging to the Most Numerous Species on the Texas Grounds (12–25 Fathoms)
(For further explanation see text)

Texas Grounds			
Syacium gunteri	52,600	Diplectrum arcuarium	4,400
Poronotus triacanthus	39,900	Centropristes philadelphicus	4,100
Cyclopsetta chittendeni	13,700	Cynoscion arenarius†	4,000
Synodus*	9,800	Trichiurus lepturus	3,000
Stenotomus caprinus	8,000	Micropogon undulatus	2,800
Cynoscion nothus†	6,800	Engyophrys sentus	1,500
Paracentropristes pomospilus	5,100	Chaetodipterus faber	1,400
Prionotus rubio	4,700		

* Mixed; see text.
† No counts are available for November.

In spite of gear selection and bias, which would reduce the numbers of gobies and eels caught, it seems perfectly clear that the Percomorphi are the most general and successful group of fishes in this environment, as they are elsewhere, followed by the Heterosomata, which are obviously adapted to bottom life. This is essentially the same situation observed by Gunter (1938a), although he found the Nematognathi more abundant in the muddy, low salinity waters of Louisiana than the Heterosomata.

Baughman (1950) comments as follows on the zoogeography of the western Gulf:

> To my mind, the western Gulf of Mexico presents an entirely separate faunal complex, cut off from Florida by the vast and silt-laden flood of the Mississippi, and from the West Indies by the deeps extending from the mouth of that river down through the Yucatan channel, past the Misteriosa and Rosalina Banks, to the southern shore of the Caribbean Sea (p. 118).

Ginsburg (1952) pointed out certain differences in the fauna of the eastern and western Gulf of Mexico. However, these differences are either artifacts due to insufficient collection or to confusion in taxonomy. For example, *Menticirrhus focaliger* was taken in the western Gulf during this investigation both on the Texas coast and on Campeche

Bank. *Centropristes melanus* may not occur in the western Gulf, but the shallow water snapper banks off Padre Island have not been collected. The seahorse, *Hippocampus regulus* lives in turtle grass, *Thalassia*, and it is difficult to collect without patience and the proper gear. Turtle grass occurs in both the eastern and western Gulf. *Hippocampus regulus* likewise is not confined to the western Gulf (see Reid, 1954).

The main differences in the fish fauna of the eastern and western Gulf will probably be one of the relative abundance of species rather than endemic species. Reid (1954) made a study of the fish fauna in the shallow water around Cedar Key, Florida. He listed all the fishes known to occur in that region. My work is only concerned with trawl caught fish, and many of the important and abundant sports fish off Port Aransas were not taken. Reid attached some importance to the absence of dolphin in his and Gunter's catches. However, neither used trolling gear so the absence is not significant. At least the dolphin, *Coryphaena hippurus*, is very abundant off Port Aransas. For example, 1,417 dolphins were caught from August 6 through August 12, 1952 by sports fishermen, according to the Port Aransas Fishing News. In regard to pushnet catches on the shallow grass flats, I have found that *Lagodon rhomboides*, *Orthopristis chrysopterus*, *Gobiosoma robustum*, *Syngnathus scovelli*, and *Syngnathus floridae* are the dominant species in Texas, and according to Reid, the same species are dominant in the Cedar Key area. The most striking difference between the two areas is in the abundance of sciaenid fishes, and, indeed, Reid does not list the common croaker, *Micropogon undulatus*, and presumably it is extremely rare at Cedar Key.

At present no species of fish has been shown convincingly to be endemic in either the eastern or western Gulf, and certainly the sweeping statement of Baughmann is a gross exaggeration.

The relationship of the temperate-water marine fish fauna of the Atlantic and northern Gulf coasts, as Gunter (1948) and Ginsburg (1952) have noted, is very close. The peninsula of Florida acts as a barrier to gene exchange between the two populations because most of the temperate-water fishes do not live or migrate around the tropical tip of Florida. Ginsburg, who has made comparative studies of morphological characters of the two populations, found that the populations diverge to a greater or lesser degree. This divergence is not always of species magnitude. The populations have been separated only since the Pleistocene emergence of the Florida barrier peninsula.

TABLE 28

Fishing Log for One Otter Trawl Drag Completed in 8½ Fathoms off Punta Morros, Campeche, Mexico*

Chloroscombrus chrysurus	4,220	Menticirrhus americanus	10
Bathystoma a. rimator	2,280	Lactophrys tricornis	10
Eucinostomus gula	560	Synodus foetens	10
Diplectrum formosum	330	Scorpaena inermis	10
Prionotus scitulus	180	Scorpaena brasiliensis	10
Etropus crossotus	70	Echeneis naucrates	5
Orthopristis chrysopterus	40	Sphyraena guachancho	2
Lagodon rhomboides	20	Sphoeroides nephelus	1
Calamus calamus	20	Citharichthys spilopterus	1
Bothus ocellatus	10	Caranx ruber	1

* Bottom shell sand; time on bottom 0305–0440; elapsed time 1 hr. 35 min.

According to Ginsburg the pairs of closely related species living on the Atlantic and north Gulf coast respectively are as follows: *Brevoortia tyrannus- B. patronus; Brevoortia*

smithi- B. gunteri; Centropristes striatus- C. melanus; Menticirrhus saxatilis- M. focaliger; and *Stenotomus chrysops- S. caprinus. Stenotomus chrysops* and *S. caprinus* are so divergent that they are placed in different genera by some authors.

Although there are a number of tropical fish which stray north along the Texas coast during the summer time, the inshore fish fauna of the southern Gulf is strikingly different from the northern Gulf. Most of these differences are quantitative rather than species differences. The differences between the fauna of the northern and southern Gulf will be only briefly sketched here, because a detailed analysis of my trawl data from Campeche Bank has not been completed. There are more species of fish on the southern Gulf coast, which is characteristic of tropical waters. I obtained 128 species of fish between 6 to 16 fathoms on Campeche Bank during February and July, 1951, while on the Texas coast I obtained 127 species between 3 and 25 fathoms during an investigation of a year's duration.

The family Haemulidae was the most abundant family on the pink shrimp grounds off Campeche during February, 1951. Nearly as abundant were the carangids (Carangidae). The bumper, *Chloroscombrus chrysurus,* was the most abundant carangid on Campeche Bank, and it is also abundant on the Texas coast. In drags completed over shell bottom, the grunt, *Bathystoma a. rimator,* was extremely abundant. Although this species has been reported from Texas, it is very rare. However, this grunt does range farther north in the eastern Gulf. The writer took a single specimen, and eight additional fish constitute the known Texas records. Other grunts such as *Haemulon plumieri* were common among the loggerhead sponges. I have seen specimens which were caught on snapper reefs near 20° 10′ N. on the Mexican coast, but none have been reported from Texas. A very distinctive flatfish, *Bothus ocellatus,* is characteristic of Campeche Bank but it is unknown in Texas waters.

There appears to be little difference in the fauna of the brown shrimp grounds in the northern and southern Gulf. Nevertheless, further investigations particularly during the winter months may show considerable divergence between the faunas of the two areas. Many more tropical fishes will undoubtedly be found at Obergon, Mexico, than in the northern Gulf.

Bathymetric Distribution

Allee *et al.* (1949, p. 341) stated that there is a greater abundance of species and individuals of marine organisms in shallow coastal waters of low salinities. Actually the greatest abundance of species is on the coastal shelf in waters of high salinity. A comparison of the shrimp trawl catches from water of less than 12 fathoms and between 12 and 25 fathoms along the Texas coast will show this relationship.

The list of species occurring in the two zones along the Texas coast was compiled from the catch data of the writer and the published papers of Gunter (1945 and 1950) on the Texas coast. Although more trawling was done between the beach and 12 fathoms and the trawling periods were separated by ten years, the greatest number of species are recorded in trawl hauls from deeper water. The species summary by groups is as follows:

	Less than 12 fathoms	*12 to 25 fathoms*
Invertebrates	58 species	59 species
Ascidians	0	2
Pisces	81	122

The greatest difference is observable in the catch of fishes, which is to be expected as the gear is best adapted to the capture of large and motile organisms. At what depth the number of species of fish declines is not known, but limited trawling in 30 to 38 fathoms off northeastern Mexico indicates that the decline sets in at a depth greater than 40 fathoms.

TABLE 29

Lists of Species Caught in Shrimp Trawls in Depths of 12 to 25 Fathoms along the Texas Coast. This compilation is composed of my data

Renilla mulleri	Molpadia cubana
Virgularia mirabilis	Styela partita
Calliactis tricolor	Styela plicata
Crepidula plana	Mustelus canis
Strombus pugilus	Carcharhinus limbatus
Phalium granulatum	Carcharhinus milberti
Sconsia striata	Carcharhinus obscurus
Distorsio clathrata	Carcharhinus porosus
Tonna galea	Sphyrna diplana
Oocorys sp.	Sphyrna tiburo
Murex fulvescens	Sphyrna tudes
Cantharus sp.	Squatina dumerili
Busycon contrarium	Pristis pectinatus
Busycon pyrum	Rhinobatus lentiginosus
Fasciolaria gigantea	Raja texana
Conus austini	Narcine brasiliensis
Polystria albida	Dasyatis sayi
Pteria colymbus	Pteroplatea micrura
Atrina serrata	Harengula pensacolae
Pecten papyraceus	Brevoortia patronus
Ostrea equestris	Anchoa hepsetus
Echinochama arcinella	Anchoa mitchilli
Laevicardium laevigatum	Congrina flava
Chione clenchi	Hoplunnis macrurus
Pitar cordata	Neoconger mucronatus
Macoma tageliformis	Uroconger sp.
Lolliguncula brevis	Gymnothorax nigromarginatus
Loligo pealei	Mystriophis intertinctus
Rossia tenera	Bagre marina
Squilla empusa	Galeichthys felis
Lysiosquilla scabricauda	Synodus foetens
Penaeus setiferus	Synodus poeyi
Penaeus aztecus	Saurida brasiliensis
Penaeus duorarum	Bregmaceros atlanticus
Trachypeneus similis	Urophycis floridanus
Sicyonia dorsalis	Paralichthys albigutta
Sicyonia brevirostris	Paralichthys lethostigma
Solenocera vioscai	Ancylopsetta quadrocellata
Scyllarides aequinoctialis	Syacium gunteri
Porcellana sayana	Citharichthys macrops
Petrochirus bahamensis	Citharichthys spilopterus
Stenorynchus seticornis	Trichopsetta ventralis
Libinia emarginata	Engyophrys sentus
Leiolambrus nitidus	Achirus fasciatus
Portunus gibbesi	Gymnachirus texae
Portunus spinimanus	Symphurus diomedianus
Callinectes sapidus	Symphurus civitatum
Callinectes danae	Symphurus plagiusa
Calappa springeri	Syngnathus louisianae
Hepatus epheliticus	Hippocampus hudsonius
Astropecten antillensis	Fistularia tabacaria
Luidia alternata	Sphyraena guachancho
Luidia clathrata	Polydactylus octonemus
Echinaster echinophorus	Scomber colias
Clypeaster ravenelli	Scomberomorus maculatus
Stichopus badionotus	Trichiurus lepturus

TABLE 29—Continued

Lists of Species Caught in Shrimp Trawls in Depths of 12 to 25 Fathoms along the Texas Coast. This compilation is composed of my data

Peprilus paru	Micropogon undulatus
Poronotus triacanthus	Menticirrhus americanus
Seriola dumerili	Cynoscion arenarius
Trachinotus carolinus	Cynoscion nothus
Selar crumenophthalmus	Caulolatilus cyanops
Trachurus lathami	Chaetodipterus faber
Caranx hippos	Scorpaena calcarata
Chloroscombrus chrysurus	Prionotus ophryas
Vomer setapinnis	Prionotus paralatus
Selene vomer	Prionotus pectoralis
Pomatomus saltatrix	Prionotus rubio
Rachycentron canadus	Prionotus scitulus
Garrupa nigrita	Prionotus stearnsi
Promicrops itaiara	Prionotus tribulus
Diplectrum arcuarium	Gobionellus gracillimus
Serraniculus pumilio	Bollmannia communis
Centropristes philadelphicus	Echeneis naucrates
Paracentropristes pomospilus	Lonchopisthes lindneri
Priacanthus arenatus	Kathetostoma albigutta
Lutianus blackfordi	Brotula barbata
Lutianus synagris	Lepophidium brevibarbe
Pristipomoides andersoni	Nautopaedium porosissimum
Rhomboplites aurorubens	Balistes capriscus
Bathystoma a. rimator	Monacanthus hispidus
Conodon nobilis	Alutera schoepfi
Orthopristes chrysopterus	Lactophrys tricornis
Stenotomus caprinus	Lagocephalus laevigatus
Lagodon rhomboides	Sphoeroides nephelus
Eucinostomus gula	Sphoeroides spengleri
Eucinostomus argenteus	Chilomycterus schoepfi
Upeneus parvus	Antennarius scaber
Larimus fasciatus	Antennarius radiosus
Stellifer lanceolatus	Ogcocephalus cubifrons
Leiostomus xanthurus	Ogcocephalus sp.
	Halieutichthys aculeatus

TABLE 30

List of Species Caught in Shrimp Trawls in Less Than 12 Fathoms Along the Texas Coast. This Compilation is Compiled of My Data and Information from Gunter (1945 and 1950)

Calliactis tricolor	Pitar texasiana
Leptogorgia setacea	Spisula solidissima
Renilla mulleri	Macoma tageliformis
Virgularia mirabilis	Barnea costata
Zoobotryon pellucidum	Lolliguncula brevis
Crepidula fornicata	Loligo pealei
Crepidula plana	Squilla empusa
Strombus alatus	Penaeus setiferus
Polynices duplicata	Penaeus aztecus
Phalium granulatum	Penaeus duorarum
Busycon contrarium	Trachypeneus similis
Busycon pyrum	Trachypeneus constrictus
Murex fulvescens	Sicyonia brevirostris
Thais haemostoma	Sicyonia dorsalis
Tonna galea	Xiphopeneus krøyeri
Oliva sayana	Porcellana sayana
Arca campechiensis	Petrochirus bahamensis
Noetia ponderosa	Libinia emarginata
Echinochama arcinella	Leiolambrus nitidus
Ostrea cristata	Portunus gibbesi
Dinocardium robustum	Callinectes sapidus
Chione cancellata	Callinectes danae
Chione clenchi	Ovalipes ocellatus

TABLE 30—Continued

List of Species Caught in Shrimp Trawls in Less Than 12 Fathoms Along the Texas Coast. This Compilation is Compiled of My Data and Information from Gunter (1945 and 1950)

Arenaeus cribrarius	Scomberomorus maculatus
Menippe mercenaria	Trichiurus lepturus
Calappa springeri	Peprilus paru
Hepatus epheliticus	Poronotus triacanthus
Persephona crinita	Hemicaranx amblyrhynchus
Persephona punctata	Caranx hippos
Astropecten antillensis	Trachurus lathami
Astropecten articulatus	Chloroscombrus chrysurus
Astropecten diplicatus	Vomer setapinnis
Luidia alternata	Pomatomus saltatrix
Luidia clathrata	Centropristes philadelphicus
Mellita quinquiesperforata	Diplectrum arcuarium
Aprionodon isodon	Lutianus blackfordi
Carcharhinus leucas	Conodon nobilis
Sphyrna tiburo	Orthopristis chrysopterus
Rhinobatus lentiginosus	Stenotomus caprinus
Raja texana	Lagodon rhomboides
Narcine brasiliensis	Eucinostomus gula
Dasyatis sabina	Eucinostomus argenteus
Dasyatis sayi	Upeneus parvus
Dasyatis americana	Larimus fasciatus
Pteroplatea micrura	Stellifer lanceolatus
Harengula pensacolae	Leiostomus xanthurus
Opisthonema oglinum	Micropogon undulatus
Brevoortia patronus	Menticirrhus americanus
Anchoa hepsetus	Menticirrhus focaliger
Anchoa mitchilli	Cynoscion arenarius
Bagre marina	Cynoscion nebulosus
Galeichthys felis	Cynoscion nothus
Urophycis floridanus	Chaetodipterus faber
Synodus foetens	Scorpaena ginsburgi
Paralichthys lethostigma	Prionotus rubio
Paralichthys albigutta	Prionotus tribulus
Ancyclopsetta quadrocellata	Prionotus pectoralis
Syacium gunteri	Prionotus scitulus
Cyclopsetta chittendeni	Astroscopus y-graecum
Citharichthys spilopterus	Rissola marginata
Citharichthys macrops	Lepophidium brevibarbe
Etropus crossotus	Otophidium welshi
Achirus lineatus	Nautopaedium porosissimum
Achirus fasciatus	Balistes capriscus
Symphurus plagiusa	Monacanthus hispidus
Symphurus civitatum	Lagocephalus laevigatus
Syngnathus louisianae	Sphoeroides nephelus
Hippocampus hudsonius	Chilomycterus schoepfi
Sphyraena guachancho	Ogcocephalus cubifrons

SOME GENERAL CONSIDERATIONS

1. Level Bottom Communities.

In recent years marine ecologists, fisheries biologists and certain paleontologists have become much interested in what has been termed the level bottom communities of the sea. This began with C. G. J. Petersen's work in Denmark about 40 years ago. He looked upon fisheries biology as essentially a branch of marine ecology and his approach was ecological in that he was trying to study the available food. He attempted quantitative methods with grabs and buckets. However, the total bottom community of the seas is composed of the in-fauna, which Petersen's samplers and their improvements will determine more or less quantitatively, plus the rapidly motile crawlers and other inverte-

brates on the surface of the bottom, plus the fast swimming fishes and invertebrates which rise and fall in the water. These cannot be sampled by Petersen's methods. Gunter (1938a) has summarized information showing that the concentration of fishes in the shallow sea is much greater near the bottom.

Methods of sampling the bottom for fast motile animals are not quantitatively but qualitatively comparable and sampling with trawls and dredges are extensions of information about the level bottom communities of the sea. They are additions in the direction of sampling entire communities. In spite of gear selectivity and bias, trawl catches are comparable from time to time and place to place. Trawls are designed to capture motile organisms and they give an extended view of the faunal community on the bottom. This approach was essentially the one used by Gunter in Louisiana and Texas on the shallow water fauna. My work is an extension of this approach into the deeper Gulf waters.

Various studies have been made on the relationship of bottom communities to bottom but in general it can be stated that *Penaeus aztecus, Callinectes danae, Pitar cordata, Busycon contrarium, Astropecten antillensis, Syacium gunterii,* and *Poronotus triacanthus* were dominant organisms offshore as compared to *Penaeus setiferus, Callinectes danae, Renilla mulleri, Pitar texasiana, Cynoscion nothus, Micropogon undulatus, Polydactylus octonemus* and *Galeichthys felis* on the inshore grounds.

There seems to be some portent that a better knowledge of this fauna will be desirable in the future and that certain comparisons with what was present in the past may be quite valuable because of the vast developments in oil and fisheries interests which are now taking place on this coast.

Various studies have been made on the relationship of bottom communities to bottom sediments, and although I made no bottom sediment studies, a log and locality descriptions have been placed in the appendix.

2. Community Designation.

Community designation by the names of organisms seems to be an attempt to qualitatively describe certain features of a phenomenon which are very difficult to analyze quantitatively. Nevertheless, they have certain quantitative aspects in that the community is usually designated by the most abundant organisms. I have set up species characterizations for the major fishing grounds on the basis of the most important crustaceans, fishes, and mollusks, because a full sampling by all types of gear (dredges, trawls and grabs) would show that these animals are the most numerous. These may be shortened into community designations, if it is desirable. They are:

The Southwest Pass grounds, characterized by *Penaeus aztecus, Squilla empusa, Prionotus rubio, Micropogon undulatus, Trichiurus lepturus* and *Syacium gunteri,* (*Penaeus aztecus- Prionotus rubio* community);

The Texas grounds, characterized by *Penaeus aztecus, Callinectes danae, Pitar cordata, Busycon perversum, Astropecten antillensis, Syacium gunteri, Poronotus triacanthus, Cyclopsetta chittendeni,* (*Penaeus aztecus- Pitar cordata- Syacium gunteri* community);

The 24–10 grounds, characterized by *Penaeus aztecus, Distorsio clathrata, Pitar cordata, Syacium gunteri, Cynoscion nothus, Synodus foetens* and *Cyclopsetta chittendeni,* (Same as Texas grounds);

The Obregon grounds, characterized by *Penaeus aztecus, Callinectes danae, Polystria albida, Paracentropristes pomospilus, Nautopaedium porosissimum, Synodus foetens* and *Syacium gunteri,* (*Penaeus aztecus- Paracentropristes pomospilus* community).

3. Certain Zoogeographical Data.

We know that the shallow water fauna—the white shrimp-croaker complex—changes to the south, between Brownsville and Tampico. This is also evident in the northeast corner of the Gulf, as shown by the absence of *Penaeus aztecus* and *Penaeus setiferus* south of Apalachicola, Florida and by observations made during an outbreak of the Red Tide (Gunter *et al.*, 1948). Reid (1954) added additional information and has shown that the faunal change in the eastern Gulf is gradual.

Unfortunately comparable work showing the substantial resemblance of the shallow water fauna of the south Atlantic coast of the United States to that of the northern Gulf has not been published. No work similar to mine has been done in the Gulf and Caribbean region except my own work on Campeche Bank, which has not been analyzed in detail. These data will be useful for zoogeographical studies whenever future work is done at similar depths in the nearby region or the south Atlantic.

SUMMARY

1. Between October 20, 1950 and August 8, 1951, I studied the bottom fauna on the shrimp beds in the western Gulf of Mexico, as sampled by the trawls of the shrimping fleet. Fifteen trips were made on eleven boats and two months, two weeks and five days were spent at sea. Two hundred and twenty-five trawl hauls were made, covering a period of nine days and nine hours of continuous trawling.

2. Specimens were identified and counted at sea and some were brought ashore for further study. A total of 430,000 fishes and 1,749,000 invertebrates was counted. These included 157 species of fishes, 104 invertebrates and two ascidians. A large number of species new to the Mexican coast were recorded and nine fishes and ten invertebrates new to the western Gulf were recorded.

3. The four major grounds for the brown shrimp and the pink shrimp grounds in the Gulf of Campeche are here for the first time delineated and described. The faunal complex or bottom communities on all the brown shrimp beds are described and they have been given community designations in terms of the most abundant animals caught. Additionally, the comparative or relative abundance of all species of fishes and invertebrates on each ground is more extensively discussed and compared with the inshore fauna, as sampled by the writer during a small number of trips and as previously delineated by Gunter for the Louisiana and Texas coasts. In brief it might be said that the Southwest Pass ground off the Louisiana coast is a *Penaeus-aztecus-Prionotus rubio* community, while the Texas grounds and the 24–10 grounds are broadly speaking *Penaeus aztecus-Pitar cordata- Syacium gunteri* communities, and the Obregon ground is a *Penaeus aztecus- Paracentropristes pomospilus* community. It should be noted, however, that the faunal complexes vary somewhat in each location, when a larger number of species are included. These facts are also discussed.

4. Each species taken was discussed individually and various natural history notes, including bathymetric distribution, are given.

5. Data were gathered on quantitative distribution of white and brown shrimp by number and pounds per acre of bottom trawled. It is clear that the brown shrimp do not

"school" extensively while the white shrimp do. The range for brown shrimp was 7.3 to 1.1 pounds per acre while the greatest range for white shrimp during a poor season was 5.4 to 1.6 pounds per acre.

6. A break-down of the number of species caught shows that the greatest numbers were taken at depths of 12 to 25 fathoms rather than at depths of 0 to 12 fathoms.

7. There is some indication of a faunal difference between the Obregon grounds and the Texas grounds, but there is a much more pronounced difference between the fauna of Campeche Bank and the Obregon grounds. Further data will be required before good zoogeographical complexes can be described.

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Appendix

Table A

The Station Log of Drags Completed During This Investigation

Table A

Table A is the station log of drags completed during this investigation. The location of the drags are dead reckoning positions, consequently they are not precisely designated. Compass courses are approximated as usually the fishermen follow a fathom contour rather than a definite compass course. The abbreviations are as follows:

C.C.P. ..... Corpus Christi Pass
C.R. ..... Colorado River
Disc. ..... Discarded
Gr.B. ..... Greens Bayou
G.I. ..... Grand Isle
M.I. ..... Mustang Island
Mtg.I. ..... Matagorda Island
N.F. ..... Net fouled
N.T. ..... Net torn (unknown cause)
P.A. ..... Port Aransas
P.Cav. ..... Pass Cavallo
P.I. ..... Padre Island
R.S. ..... Rough Seas
Sab. ..... Sabine
S.B. ..... Sabine Bank
S.M. ..... Sandy Mud
Sft.M. ..... Soft Mud
S.S. ..... Ship Shoals
St.J. ..... St. Joseph Island

OCTOBER

Shrimp Trawler "San Jacinto"

Drag No.	Date	Location	Compass Course	Depth	Time	Duration	Bottom	Remarks
1	10/20/50	E. of P.A.	NE–SSW	15½–18½	1710–2030	3 h. 20 m.	Mud	
2	"	E. of M.I.	SW	18½	2030–2300	2 h. 30 m.	Mud	Rough Sea
3	10/21/50	E. of M.I.	SW	15½	1855–2200	3 h. 5 m.	Mud	
4	"	E. of M.I.	SE	12–15	2210–0210	4 h.	Sft. M.	
5	10/22/50	E. of St.J.	SE	15	0210–0600	3 h. 50 m.	Mud	
6	"	N. of P.Cav.	Varied	3–6	1020–1230	2 h. 10 m.	Mud	
7	"	N. ofP.Cav.	"	3–6	1230–1440	2 h. 10 m.	Mud	
8A	"	20 m. N. of P.	"	15	1850–2130	2 h. 40 m.	Mud	
8B	10/23/50	Gr.B. to C.R.	"	3–7	0630–0815	1 h. 45 m.	Mud	
9	"	"	"	3–5	0825–1015	1 h. 50 m.	S.M.	
10	"	"	Parallel Beach	3–4	1025–1200	1 h. 35 m.	S.M.	
11	"	"	"	3–4	1210–1400	1 h. 50 m.	S.M.	
12	"	"	Varied	3–6	1410–1615	2 h. 5 m.	S.M.	
13	"	"	Varied	6–8	1620–1810	1 h. 50 m.	S.M.	
14	10/24/50	"	"	3–4	0805–0830	25 m.	Mud	Discard
15	"	4 mi. S. of P.Cav.	S	5	1230–1430	2 h.	S.M.	
16	10/24/50	Off Mtg.I.	SW	16	1805–2155	3 h. 50 m.	Mud	
17	"	"	SW	16	2200–0200	4 h.	Mud	
18	10/25/50	Off St. J. I.	SW	16	0200–0545	3 h. 45 m.	Mud	
Total 19 drags						48 h. 40 m.		

* Full moon 10/25/50.

NOVEMBER*

Shrimp Trawler "Rio Bravo"

Drag No.	Date	Location	Compass Course	Depth	Time	Duration	Bottom	Remarks
1	11/16/50	Sebree to Steamer	Varied	18	1740–2100	3 h. 20 m.	S.M.	Dry doors
2	"	"	"	18–17	2110–0030	3 h. 20 m.	Mud	Snag
3	11/17/50	"	"	17	0100–0400	3 h.	Mud	
4	"	"	"	17½	0400–0730	3 h. 30 m.	Mud	
5	"	"	"	19	1715–2000	2 h. 45 m.	Sft. M.	
6	"	"	"	19	2100–0010	3 h. 10 m.	Sft. M.	Net fouled Rough sea
7	11/18/50	"	"	19	0010–0350	3 h. 40 m.	Mud	Net fouled Rough sea
8	"	"	"	19	0410–0800	3 h. 50 m.	Mud	Rough sea, Snag
9	"	"	"	19	0830–1210	3 h. 40 m.	Mud	Rough sea
10	"	"	"	18–19	1225–1630	4 h. 5 m.	Mud	Rough sea
11	"	"	"	18	2025–2230	2 h. 5 m.	Mud	Rough sea
Total 11 drags						36 h. 25 m.		

* Full moon 11/24/50.

DECEMBER*

Shrimp Trawler "Gypsy Girl"

Drag No.	Date	Location	Compass Course	Depth	Time	Duration	Bottom	Remarks
1	12/ 9/50	E. of St.J. I.	Varied	16	1725–2130	4 h. 5 m.	Mud	
2	"	"	"	18	2200–0215	4 h. 15 m.	Mud	
3	"	"	NNE	17	0315–0630	3 h. 15 m.	Mud	
4	12/10/50	"	NE	15–17	1900–2145	2 h. 45 m.	Mud	
5	"	E. of Mtg. I.	NE	18	2200–0240	4 h. 40 m.	Mud	
6	12/11/50	"	Varied	18	0300–0710	4 h. 10 m.	Mud	
7	"	"	"	10	0945–1230	2 h. 45 m.	Mud	
8	12/11/50	ESE of P.Cav.	"	17	1725–2150	4 h. 25 m.	Mud	
9	"	E. of Mtg.I.	S	17	2200–0200	4 h.	Mud	
10	12/12/50	E. of St.J.I.	WSW	17	0230–0710	4 h. 40 m.	Mud	
11	"	"	WSW	18	1750–2215	4 h. 25 m.	Mud	Rough Sea
12	"	"	SWS	19–20	2315–0320	2 h. 5 m.	Mud	Rough Sea
Total 12 drags						47 hr. 30 m.		

* Full moon 12/23/50.

DECEMBER*

Shrimp Trawler "Dr. Billy"

Drag No.	Date	Location	Compass Course	Depth	Time	Duration	Bottom	Remarks
1	12/18/50	WSW Freeport	WSW	18	1740–2200	4 h. 20 m.	Mud	
2	"	S. of G.B.	"	18	2230–0230	4 h.	S.M.	
3	12/19/50	"	NE	24	0330–0730	4 h.	S.M.	
4	"	"	NE	23–25	1800–2200	4 h.	S.M.	
Total 4 drags						16 h. 20 m.		

* Full moon 12/23/50.

JANUARY*

Shrimp Trawler "Sabine No. 1"

Drag No.	Date	Location	Compass Course	Depth	Time	Duration	Bottom	Remarks
1	1/ 4/51	E. of P.A.	S	17–18	1920–2315	3 h. 55 m.	Sft. M.	
2	"	E. of M.I.	SW	18	2340–0340	4 h.	Mud	Shark?
3	1/ 5/51	Off C.C.P.	SE-SW	24	0400–0830	4 h. 30 m.	Sft. M.	
4	"	Off N.P.I.	SSW	18–24	1750–2200	4 h. 10 m.	Mud	
5	"	"	NNE	24	2210–0230	4 h. 20 m.	Mud	
6	1/ 6/51	"	"	24	0240–0710	4 h. 30 m.	S.M.	
Total 6 drags						25 h. 25 m.		
			Shrimp Trawler "Gypsy Girl"					
1	1/22/51	E. of P.A.	S	18½	1900–2300	4 h.	Mud	
2	"	"	S	18½	2300–3000	4 h.	Mud	
3	1/23/51	"	NNE	20–21½	0310–0730	4 h. 20 m.	Mud	
4	"	"		23½	1745–2140	3 h. 55 m.	Mud	Sharks or Conchs
Total 4 drags						16 h. 15 m.		

* Full moon 1/22/51.

MARCH*

Shrimp Trawler "Capt. Geo. Hamilton"

Drag No.	Date	Location	Compass Course	Depth	Time	Duration	Bottom	Remarks
1	3/ 5/51	Near 25° N.	S	21	2000–0000	4 h.	Mud	
2	3/ 6/51	"	S	21–31	0030–0730	7 h.	Mud	
3	"	Near 24° 10′ N.	S	31–35	1830–2230	4 h.	Mud	
4	3/ 6/51	"	S	37	2230–0230	4 h.	Mud	
5	3/ 7/51	"	SE	32–35	0300–0730	4 h. 30 m.	S.M.	Snag
6	"	"	N	31–36	1915–2230	3 h. 15 m.	S.M.	
7	"	"	S	32–37	2300–0300	4 h.	Mud	
8	3/ 8/51	"	"	32–34	2000–0130	5 h. 30 m.	S.M.	
9	3/ 9/51	"	"	32	0230–0630	4 h.	Mud	
10	"	"	N	32–33	1930–0100	5 h. 30 m.	Mud	
11	3/10/51	"	S	32–34	0130–0600	4 h. 30 m.	Mud	
12	"	"	Varied	32–34	1830–2200	3 h. 30 m.	Mud	
13	3/10/51	"	N	36–45	2215–0115	3 h.	Mud	Short cables
14	3/11/51	"	N	35–37	0145–0700	5 h. 15 m.	Mud	Net torn
Total 14 drags						62 h. 15 m.		
15	3/14/51	ENE of Brazos Santiago	N	24	1800–2400	6 h.	Mud	
16	3/15/51	"	S	24	0100–0700	6 h.	Mud	
Total 2 drags						12 h.		

* Full moon 3/23/51.

APRIL*

Shrimp Trawler "Forty Fathom No. 34"

Drag No.	Date	Location	Compass Course	Depth	Time	Duration	Bottom	Remarks
1	4/12/51	SE of P.A.	SSW	21–22	1820–2230	4 h. 10 m.	Mud	
2	4/12/51	"	SSW	18–21	2300–0600	7 h.	Mud	Shark?
Total 2 drags						11 h. 10 m.		

* Full moon 4/21/51.

MAY*

Shrimp Trawler "Capt. Geo. Hamilton"

Drag No.	Date	Location	Compass Course	Depth	Time	Duration	Bottom	Remarks
1	5/ 5/51	Off P.Cav.	NE	22	1800–0030	6 h. 30 m.	Mud	Shark
2	5/ 6/51	ESE of C.R.	NE	18	0120–0600	4 h. 40 m.	"	
3	5/12/51	30 mi. S. of P.A.	S	17	2045–0210	5 h. 25 m.	"	Snag
4	5/13/51	40 mi. S. of P.A.	S	17	0400–0900	5 h.	"	
5	"	50 mi. S. of P.A.	S	17	0920–1400	4 h. 40 m.	"	
6	"	50 mi. S. of P.A.	N	17	1420–1830	4 h. 10 m.	"	
7	"	50 mi. S. of P.A.	S	17	1840–0010	5 h. 30 m.	"	
8	5/14/51	Near 27° N.	S	17	0030–0705	6 h. 35 m.	"	Rough Sea
9	"	"	V	18–20	0730–1300	5 h. 30 m.	"	Rough Sea
10	"	"	V	21–22	1330–1745	4 h. 15 m.	"	Rough Sea
11	"	"	V	21	1800–1920	1 h. 20 m.	"	Snag
12	5/15/51	"	V	22	1430–1830	4 h.	"	Rough Sea
13	"	"	V	23–20	1850–0020	5 h. 30 m.	"	Snag
14	5/16/51	"	V	18–20	0200–0600	4 h.	"	Rough Sea
15	"	"	V	20–22	0630–1130	5 h.	"	Rough Sea
16	"	"	V	20–22	1145–1840	6 h. 55 m.	"	Shark
17	"	"	V	18	1930–2400	4 h. 30 m.	"	Rough Sea
18	5/17/51	"	V	20–23	0040–0550	5 h. 10 m.	"	Rough Sea
19	"	"	V	21–22	0630–1210	5 h. 40 m.	"	Rough Sea
20	"	"	V	21–24	1240–1830	5 h. 50 m.	"	Rough Sea
21	5/17/51	"	V	21–23	1900–2400	5 h.	"	Rough Sea, Snag
Total 21 drags						105 h. 10 m.		

* Full moon 5/21/51.

JUNE*

Shrimp Trawler "Francis Lee"

Drag No.	Date	Location	Compass Course	Depth	Time	Duration	Bottom	Remarks
1	6/15/51	SW Buoy at Sab.	V	6¾	0900–1100	2 h.	S.M.	
2	"	"	V	6¾	1130–1230	1 h.	"	
3	"	"	V	6¾	1330–1430	1 h.	"	
4	"	"	V	6¾	1435–1545	1 h. 10 m.	"	
5	6/16/51	18 mi. W. of Sab.	V	6½	1030–1200	1 h. 30 m.	"	
6	"	20 mi. W. of Sab.	V	6½	1200–1330	1 h. 30 m.	"	
7	"	Off S.B.	V	6½	1340–1550	2 h. 10 m.	"	
8	"	Off S.B.	V	6½	1600–1800	2 h.	"	
Total 8 drags						12 h. 20 m.		

Shrimp Trawler "Alexandra C"

1	6/17/51	SSW of S.	V	6¾	0820–1050	2 h. 30 m.	S.M.	
2	"	"	V	6¾	1100–1120	20 m.	"	
Total 2 drags						2 h. 50 m.		

Shrimp Trawler "Mister Mac"

1	6/27/51	SSE of G.I., La.	V	19	2145–0130	3 h. 45 m.	Mud	
2	6/28/51	"	V	24–23	0135–0500	3 h. 25 m.	"	
3	"	NE of SS Buoy	V	12–13	1055–1345	2 h. 50 m.	"	
4	"	"	V	12–13	1400–1700	3 h.	"	
5	"	"	V	12–13	1730–2040	3 h. 10 m.	"	
6	"	"	V	12	2100–0035	3 h. 35 m.	"	
Total 6 drags						19 h. 45m.		

* Full moon 6/19/51.

JULY*

Shrimp Trawler "Capt. Geo. Hamilton"

Drag No.	Date	Location	Compass Course	Depth	Time	Duration	Bottom	Remarks
1	7/ 5/51	N.P.I.	S	15	2230–0245	4 h. 15 m.	Mud	
2	7/ 6/51	"	S	12–15	0300–0630	3 h. 30 m.	"	
3	"	"	S	12–14	2000–2310	3 h. 10 m.	"	
4	"	"	S	12–15	2315–0300	3 h. 45 m.	"	
5	7/ 7/51	"	S	16–18	0315–0715	4 h.	"	
6	"	Near 27° N.	S	14	1910–2145	2 h. 35 m.	"	
7	"	"	S	14–15	2200–0030	2 h. 30 m.	"	
8	7/ 8/51	"	V	15–16	0100–0330	2 h. 30 m.	"	
9	"	"	V	15	0345–0630	2 h. 45 m.	"	
10	"	"	V	15	1900–2200	3 h.	"	
11	"	"	V	15	2230–0230	4 h.	"	
12	7/ 9/51	"	V	16	0345–0730	3 h. 45 m.	"	
13	"	"	V	14½	1800–2100	3 h.	"	
14	"	"	V	15	2200–0100	3 h.	"	
15	7/10/51	"	V	15	0200–0400	2 h.	"	Net Torn
16	"	"	V	15	0700–1000	3 h.	"	
17	7/10/51	"	V	15	1430–1715	2 h. 45 m.	"	
18	"	"	V	15	1730–2015	2 h. 45 m.	"	
19	"	"	V	16–17	2045–0030	3 h. 45 m.	"	
20	7/11/51	"	V	17	0100–0315	2 h. 15 m.	"	
21	"	"	V	18	0330–0630	3 h.	"	
Total 21 drags						65 h. 15 m.		

Shrimp Trawler "Texas Clipper"

8A	7/29/51	Obregon	V	18–19	1900–2115	2 h. 15 m.	Mud	
8B	"	"	V	19	2130–2330	2 h.	"	
9	"	"	V	17	2345–0205	2 h. 20 m.	"	
10	7/30/51	"	V	18–19	0230–0430	2 h.	"	
11	"	"	V	19½	0445–0650	2 h. 5 m.	"	
12	"	"	V	19–20	1905–2105	2 h.	Mud-silt	
13	"	"	V	19–20	2130–0030	3 h.	Sandy-mud	
14	7/31/51	"	V	17	0050–0350	3 h.	Mud	
15	"	"	V	17–19	0405–0720	2 h. 15 m.	"	
16	"	"	V	17–19	1845–2115	2 h. 30 m.	"	
17	"	"	V	17–19	2140–0020	2 h. 40 m.	"	Net Torn
Total 11 drags						27 h. 5 m.		

* Full moon 7/18/51.

AUGUST*

Shrimp Trawler "Texas Clipper"

Drag No.	Date	Location	Compass Course	Depth	Time	Duration	Bottom	Remarks
18	8/ 1/51	Obregon	V	19	0150–0415	2 h. 25 m.	Mud	
19	"	"	V	19	0435–0640	2 h. 5 m.	"	
20	"	"	V	19	2125–0030	3 h. 5 m.	"	Net torn
21	"	"	V	17–19	1855–2055	2 h.	"	
22	8/ 2/51	"	V	19	0150–0520	3 h. 30 m.	"	
23	"	"	V	19–17	1900–2140	2 h. 40 m.	"	
24	"	"	V	19	2130–0030	3 h.	"	
25	8/ 3/51	"	V	16–18	0150–0410	2 h. 20 m.	"	
26	"	"	V	17–18	0430–0650	2 h. 20 m.	"	
27	"	"	V	15	2120–0005	2 h. 45 m.	"	
28	8/ 4/51	"	V	15–16	0020–0300	2 h. 40 m.	"	
29	"	"	V	15–16	0320–0630	3 h. 10 m.	"	
30	"	"	V	15	1820–2100	2 h. 40 m.	"	
31	"	"	V	15	2115–2330	2 h. 15 m.	"	
32	"	"	V	14–15½	2345–0245	3 h.	"	

AUGUST—Continued

Shrimp Trawler "Texas Clipper"

Drag No.	Date	Location	Compass Course	Depth	Time	Duration	Bottom	Remarks
33	8/ 5/51	"	V	15½	0300–0500	2 h.	Mud	
34	"	"	V	15–16½	0515–0655	1 h. 40 m.	"	
35	"	"	V	18	1825–2050	2 h. 25 m.	"	
36	"	"	V	18	2105–2345	2 h. 40 m.	"	
37	8/ 6/51	"	V	18–19	0005–0235	2 h. 30 m.	"	
38	"	"	V	19	0245–0430	1 h. 45 m.	"	
Total 21 drags						52 h. 55 m.		

* Full moon 8/16/51.

Table B

The Shrimp Log of Drags Completed During This Investigation

Table B

Table B is the shrimp log of this investigation. All drags were recorded quantitatively. The abbreviations are as follows:

"A" ..... "Alexandra C."
"CGH" ..... "Capt. Geo. Hamilton"
"DB" ..... "Dr. Billy"
"FL" ..... "Francis Lee"
"FF" ..... "Forty Fathom No. 34"
"GG" ..... "Gypsy Girl"
"M" ..... "Mister Mac"
M ..... mostly
"RB" ..... "Rio Bravo"
"S" ..... "Sabine No. 1"
"SJ" ..... "San Jacinto"
"TC" ..... "Texas Clipper"

Penaeus setiferus

OCTOBER

Drag No.	*Commercial landings* Weight in pounds heads on	Count	*Discards* Weight in pounds heads on	Count
6	250	15/26	20	36/65
7	210	15/26	5	"
8b	635	15/36	50	"
9	415	15/26	10	"
10	390	15/36	450	"
11	285	15/36	300	"
12	510	15/26	10	"
13	285	M. 15/21 F. 21/26	5	"
14	Discarded*			
15	175	21/30	5	"
Total	3155	Av. 25	900	Av. 45

* Very few shrimp and lots of trash fish.

NOVEMBER

Drag No.	Number of shrimp	Count
8	7	15/20
9	30	15/20

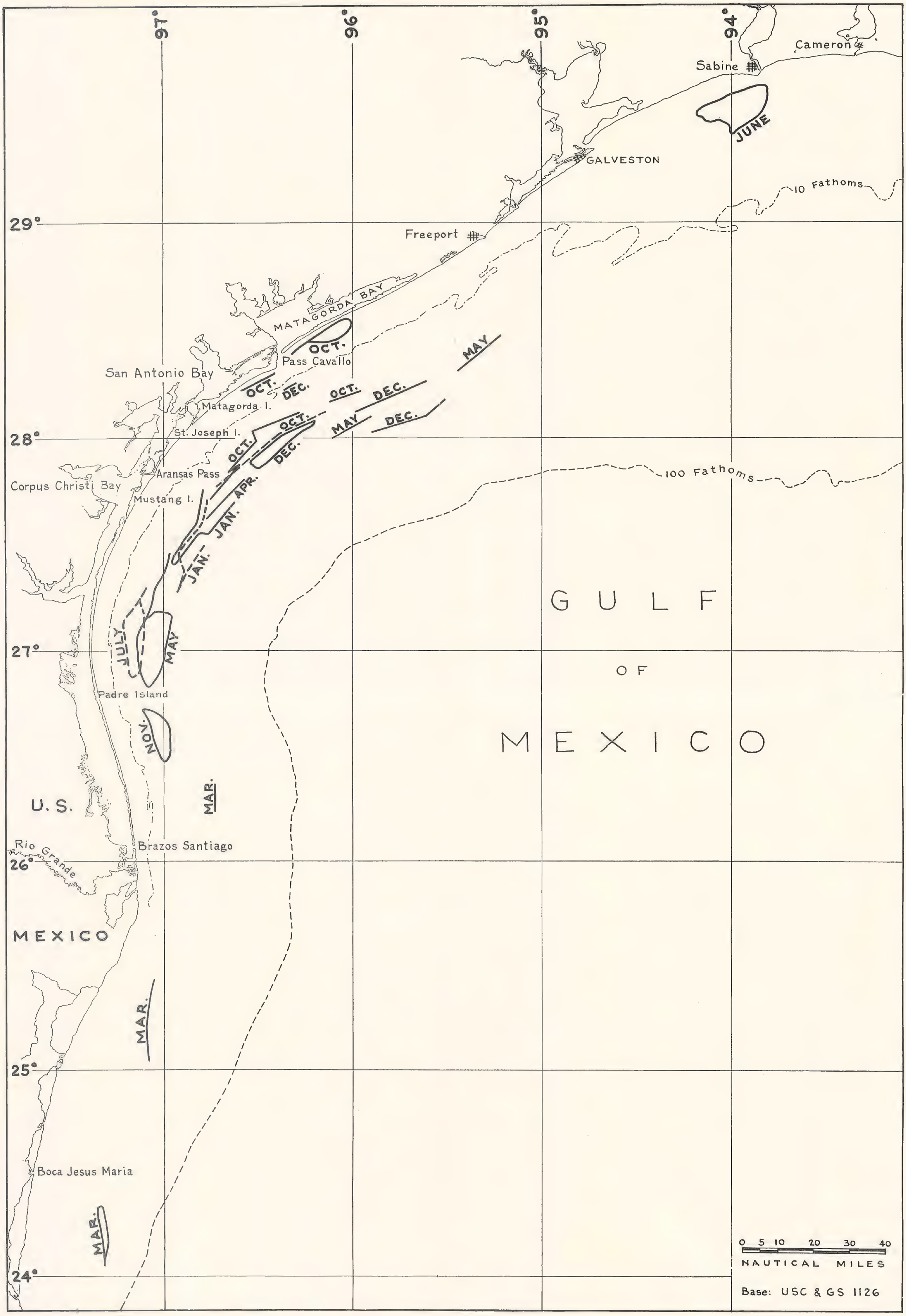

FIGURE 6

Locations of Trawling Operations conducted by the writer between Cameron, Louisiana and Sugarloaf Mountain (23° 15 N'.)

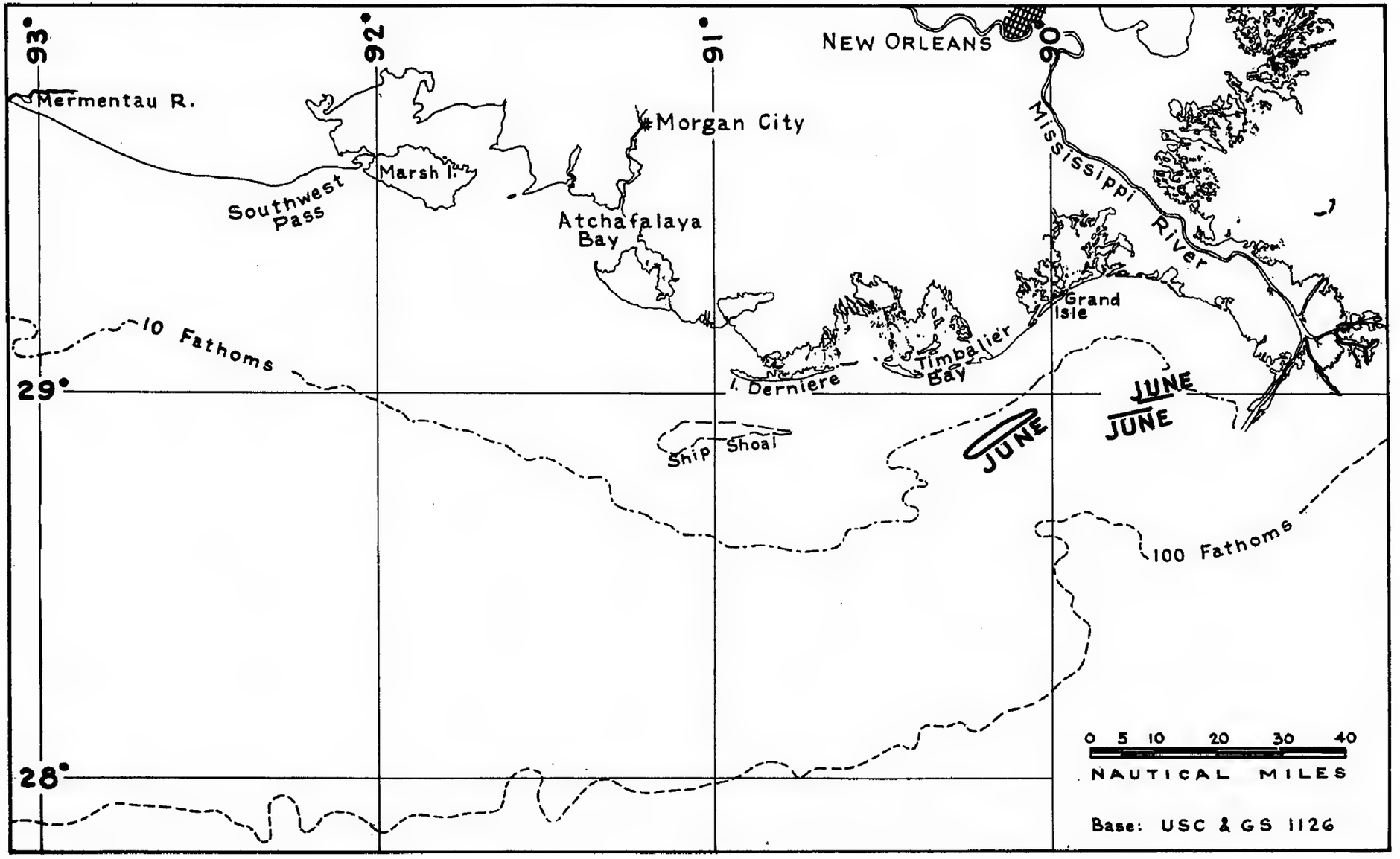

FIGURE 7

Locations of Trawling Operations conducted by the writer between Cameron, Louisiana and the mouth of the Mississippi

DECEMBER

Drag No.	Weight in pounds headless	Weight in pounds heads on	Count
7	85	140	15/30

MAY

Drag No.	Number of Shrimp	Count
4	1	15/20
5	40	"
14	4	"
15	4	"
17	5	"
20	25	"

JUNE

Drag No.	pounds headless Weight in	Weight in pounds heads on	Count
"FL" 1	120	200	21/30
" 2	140	235	"
" 3	50	85	"
" 4	50	85	"
" 5	100	165	"
" 6	90	150	"
" 7	130	210	"
" 8	100	170	"
Total "FL"	780	1300	
"A" 1	125	210	21/30
" 2	10	15	"
Total "A"	135	225	
"M" 3	120	200	21/36
" 4	160	265	"
" 5	275	460	"
" 6	40	65	"
Total "M"	595	990	

Penaeus aztecus

OCTOBER

Drag No.	Weight in pounds headless	Weight in pounds heads on	Count
1	210	350	15/30
2	105	175	"
3	230	385	"
4	295	490	"
5	315	525	"
8a	125	210	"
16	230	385	"
17	275	470	"
18	210	350	"
Total	1995	3330	

NOVEMBER

Drag No.	Weight in pounds headless	Weight in pounds heads on	Count
1	170	285	15/26
2	250	415	"
3	335	560	"
4	460	765	"

NOVEMBER

Drag No.	Weight in pounds headless	Weight in pounds heads on	Count
5	460	765	15/26
6	125	210	"
7	125	210	"
8	295	490	"
9	465	775	"
10	570	950	"
11	125	210	"
Total	3380	5635	"

DECEMBER

Drag No.	Weight in pounds headless	Weight in pounds heads on	Count
"GG" 1	295	490	15/30
" 2	295	490	"
" 3	265	440	"
" 4	225	375	"
" 5	250	410	"
" 6	355	590	"
" 8	295	490	"
" 9	335	560	"
" 10	380	635	"
" 11	160	265	"
" 12	250	410	"
Total	3105	5155	
"DB" 1	170	285	15/30
" 2	250	415	"
" 3	210	350	"
" 4	210	350	"
Total	840	1400	Av. 22

JANUARY

Drag No.	Weight in pounds headless	Weight in pounds heads on	Count	Discards
"S" 1	170	285	M. 21/25	Very few
" 2	60	100	M. "	" "
" 3	265	440	M. "	" "
" 4	310	515	M. "	" "
" 5	375	625	M. "	" "
" 6	375	625	M. "	" "
Total	1545	2590	Av. 22	
"GG" 1	195	310	15/25	
" 2	125	205	"	
" 3	185	310	"	
" 4	0	0		
Total	495	825	Av. 22	

MARCH*

Drag No.	Weight in pounds headless	Weight in pounds heads on	Count
1	125	210	M. 12/20 V.F. 21/25
2	200	335	" " " "
3	185	310	" " " "
4	185	310	" " " "
5	200	335	" " " "
6	125	210	" " " "
7	125	210	" " " "
8	265	440	" " " "

MARCH*

Drag No.	Weight in pounds headless	Weight in pounds heads on	Count
9	185	310	M. 12/20 Very few 21/25
10	250	415	" " " "
11	200	335	" " " "
12	30	50	" " " "
13	30	50	" " " "
14	15	25	" " " "
Total	2120	3545	Av. 16

* 24–10 grounds.

MARCH*

Drag No.	Weight in pounds headless	Weight in pounds heads on	Count
15	190	315	15/30 M. 15/20
16	395	660	" " "
Total	585	975	

* Texas grounds.

APRIL

Drag No.	Weight in pounds headless	Weight in pounds heads on	Count
1	85	145	M. 15/20
2	10	15	" "
Total	95	160	Av. 20

MAY

Drag No.	Weight in pounds headless	Weight in pounds heads on	Count	No. Discards	Count
1	15	25	15/26	Very few	36/100
2	140	235	"	" "	"
3	125	210	"	" "	"
4	125	210	"	" "	"
5	185	310	"	" "	"
6	190	315	"	" "	"
7	200	335	"	" "	"
8	250	415	"	" "	"
9	265	440	"	" "	"
10	250	415	"	" "	"
11	95	160	"	" "	"
12	185	310	"	" "	"
13	0				
14	215	360	"	" "	"
15	185	310	"	" "	"
16	0				
17	75	125	"	" "	"
18	265	440	"	200	"
19	310	515	"	200	"
20	250	415	"	Few	"
21	185	310	"	Very few	"
Total	3510	5855			

JUNE*

Drag No.	No. of Discards	Count
"FL" 1	100	36/70
" 2	200	"
" 3	100	"
" 4	100	"
" 5	50	"
" 6	50	"
" 7	1000	"
" 8	1000	"
"A" 1	few	"
" 2	few	"

Drag No.	Weight in pounds headless	Weight in pounds heads on	Count	No. Discards	Count
"M" 1	140	235	15/30	Very Few	65/100
" 2	300	500	"	" "	"
" 3	40	70	15/42	" "	"
" 4	40	70	"	" "	"
" 5	85	140	"	" "	"
" 6	170	280	"	" "	"
Total	685	1,295	Av. 25		

JULY

1	60	100	15/25	Few	30/70
2	175	290	15/30	"	"
3	175	290	"	10,000	"
4	280	465	"	13,000	"
5	30	50	"	3,100	"
6	420	700	"	2,200	"
7	300	500	15/42	Few	"
8	105	175	"	1,600	42/70
9	300	500	"	Few	"
10	365	610	"	"	"
11	650	1,085	"	"	"
12	35	70	"	"	"
13	315	525	"	"	"
14	315	525	"	"	"
15	120	200	"	"	"
16	55	90	"	400	"
17	260	435	"	250	"
18	400	665	15/70	none	
19	665	1,110	"	"	
20	665	1,110	"	"	
21	75	125	15/20	100	30/70
Total	5,765	9,620	Av. 36		

JULY–AUGUST*

Drag No.	Weight in pounds headless	Weight in pounds heads on	Count	No. Discards	Count
8a	380	635	15/30	2,800	31/70
8b	380	635	"	1,400	"
9	425	710	M.26/30	8,000	"
10	615	1,000	15/30	2,000	"
11	260	435	M.15/30	500	"
12	330	550	M.15/20	1,200	"
13	380	635	M.15/20	Few	"
14	425	710	M.21/30	"	"
15	315	525	M.26/30	"	"
16	300	500	M.15/40	"	"
17	95	160	M.21/25	Very few	"
18	350	585	"	" "	"
19	280	465	"	" "	"

JULY–AUGUST*

Drag No.	Weight in pounds headless	Weight in pounds heads on	Count	No. Discards	Count
20	425	710	M.15/30	Very few	31/70
21	425	710	"	"	"
22	380	635	"	"	"
23	285	475	"	800	"
24	350	585	15/25	Very few	"
25	540	900	"	"	"
26	570	950	26/30	1,400	"
27	350	585	26/35	8,000	"
28	425	710	15/30	Few	"
29	710	1,185	"	"	"
30	270	450	"	"	"
31	190	315	"	"	"
32	350	590	"	"	"
33	310	515	"	"	"
34	95	160	"	"	"
35	310	515	"	"	"
36	270	450	"	"	"
37	325	540	"	"	"
38	180	300	"	"	"
Total	11,300	18,825	†		

* Obregon grounds.
† 15/20's 70 per cent; 21/25 10 per cent; 26/30 15 per cent; 30/65 5 per cent.